15 ASUNCION

15.1 Introduction

The island of Asuncion is the third-most northerly island of the 14 islands that make up the Commonwealth of the Northern Mariana Islands (CNMI) and is located at 19°41′ N, 145°24′ E. This island is also known as Asonson, Assongsong, and Asumption. Asuncion is ~ 3 km wide and 3.3 km long and has a land area of 7.86 km^2 (Fig. 15.1a). This island is a steep-sided volcanic cone. The rim of this volcano's crater is the highest point on Asuncion, an elevation of 857 m, and is surrounded by steep slopes that culminate in sea cliffs at the coasts of this island (Fig. 15.1b).

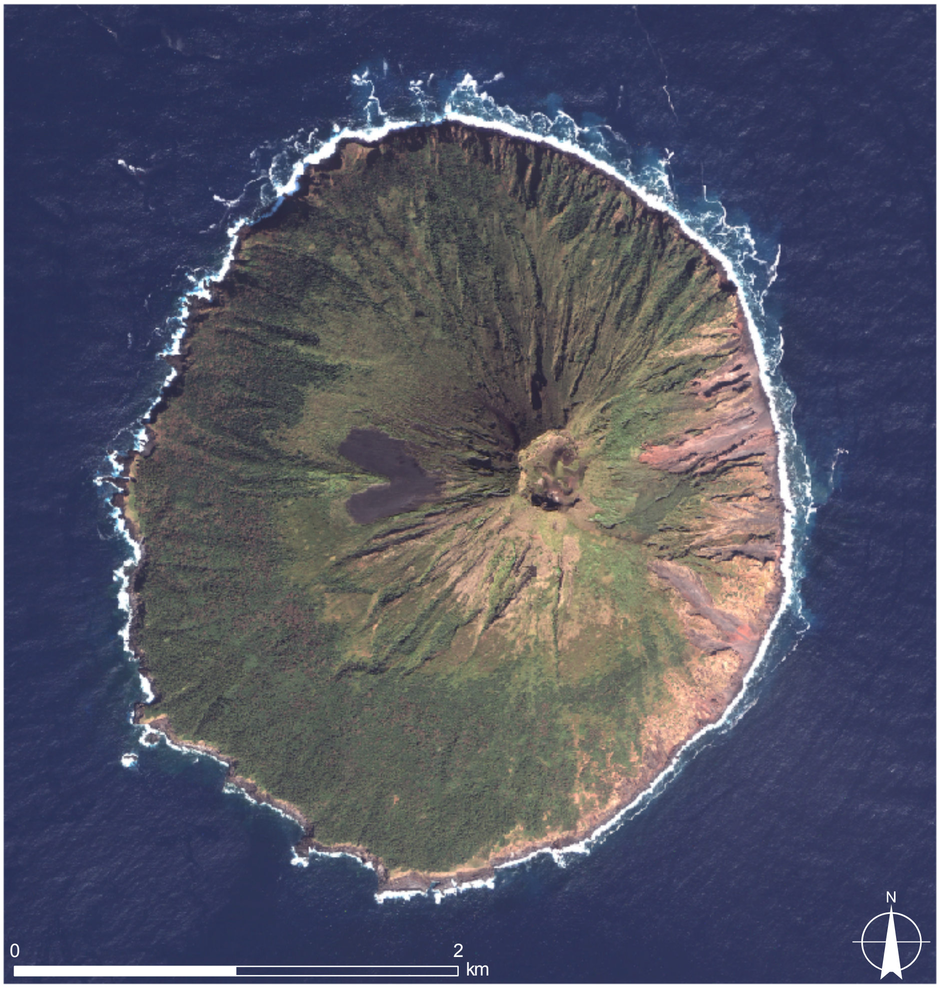


Figure 15.1a. Satellite image of Asuncion (© 2004 DigitalGlobe Inc. All rights reserved).

Figure 15.1b. The steep flanks of Asuncion, as seen from the NOAA Ship *Hi`ialakai* in 2007. *NOAA photo*

15.1.1 History and Demographics

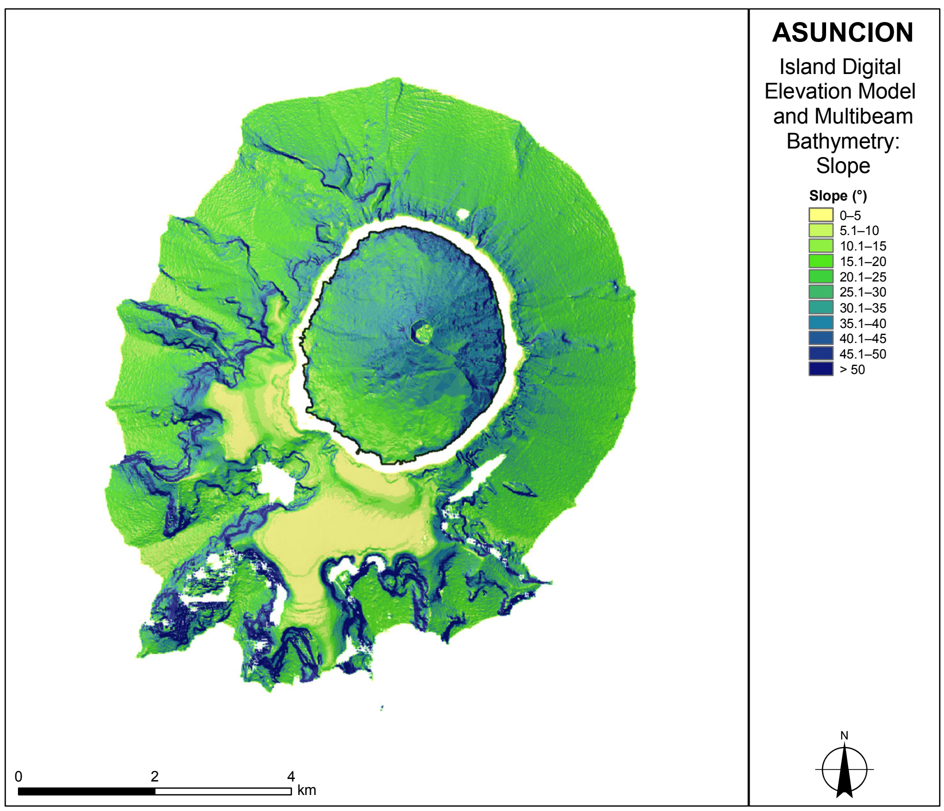
Asuncion is currently unpopulated. As on other islands in the CNMI, Spain in 1695 forced any inhabitants to relocate to Guam (Rogers 1995), and, from then on, Asuncion has been inhabited only intermittently (Mueller-Dombois and Fosberg 1998). In 1909, while under rule by Germany, Asuncion was leased to the Pagan Gesellschaft, a trading association, for exploitation of bird plumage for a period of 3 years, along with Farallon de Pajaros, Maug, Agrihan, Guguan, Sarigan, and Farallon de Medinilla (Spennemann 1999b). During this time, Japanese bird catchers employed on these islands may have resided on Asuncion temporarily, and other fishing or hunting parties also may have resided periodically on this island. Since 1978, the CNMI Constitution has prohibited inhabitation of Asuncion (CNMI Constitution).

Asuncion falls within the Northern Islands Municipality of the CNMI, and the political history of Asuncion follows that of the CNMI as a whole, which is described in more detail in Chapter 1: "Introduction" and Chapter 8: "Saipan," Section 8.1.1: "History and Demographics."

15.1.2 Geography

Asuncion is the steepest of the northern volcanic islands of the Mariana Archipelago (Fig. 15.1.2a). High sea cliffs bound the steepest slopes, located on the northeastern side of Asuncion, and, in contrast, the gentler southwestern slopes are bordered by much lower sea cliffs (Siebert and Simkin 2002–). The southwestern and western flanks are mantled by ash deposits, and landslide scars mark this island's southern flanks.

Figure 15.1.2a. Combined slope map using the digital elevation model and bathymetric data for Asuncion (grid cell size: 10 m).



The most recent confirmed volcanic eruption occurred in 1906, producing lava flows that descended down the southeastern and western flanks. Another eruption may have occurred in 1924 but is unconfirmed (Siebert and Simkin 2002–). More recently, volcanologists observed active fumaroles within the summit crater during a visit in 1992 (Siebert and Simkin 2002–).

In comparison to many other islands of the CNMI, Asuncion is abundantly vegetated (Fig. 15.1.2b). Sword grass occurs on its upper slopes, and the lower slopes are heavily forested (Pacific Protected Areas Database). Coconut groves occur on the lowest slopes of the southern and southwestern flanks and on areas of flat land (Mueller-Dombois and Fosberg 1998).

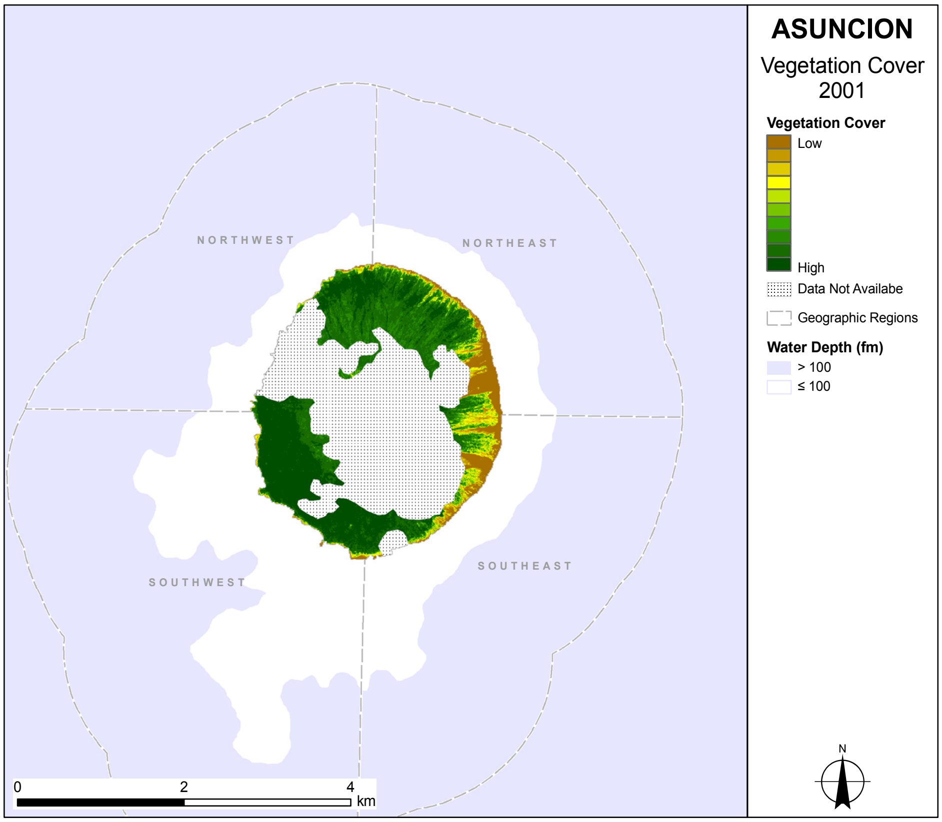


Figure 15.1.2b. Vegetation cover on Asuncion, derived using the Normalized Difference Vegetation Index from a satellite image (grid cell size: 4 m; IKONOS Carterra Geo Data, 2001). Hatched lines display areas where data are not available because cloud cover obscures the satellite image.

15.1.3 Environmental Issues on Asuncion

The native, tropical, dry forest supported on Asuncion is the best developed in the CNMI. The most extensive forest type is scrubby, mixed-broadleaved forest, dominated by species of the deciduous tree genus *Terminalia*. The seeds of these indigenous trees are edible to both humans and animals and are dispersed by fruit bats. Species of *Terminalia* occur on the southern slopes of Asuncion, above the coconut groves on the southern and southwestern flanks and on the lower slopes of the western flanks (World Wildlife Fund 2001).

Asuncion is part of a protected reserve established under Article XIV of the CNMI Constitution and managed by the CNMI Division of Fish and Wildlife. This legislation states that Asuncion is to remain an uninhabited place, and no permanent structures can be built on this island, except for the purposes of preservation and protection of natural resources (CNMI Constitution). Asuncion is preserved as a habitat for birds, wildlife, and plants. Specifically, 25 bird species are protected on this island, including the Micronesian starling (*Aplonis opaca*), the Micronesian honeyeater (*Myzomela rubrata*), and small numbers of the Micronesian megapode (*Megapodius laperouse*), which is listed Federally as endangered and locally as threatened or endangered (Pacific Protected Areas Database; U.S. Fish and Wildlife Service; Berger et al. 2005). The Mariana fruit bat (*Pteropus mariannus mariannus*), an endemic subspecies listed Federally as threatened (U.S. Fish and Wildlife Service) and locally as threatened or endangered (Berger et al. 2005), is also present on this island (Pacific Protected Areas Database). Asuncion is 1 of only 3 northern islands of the CNMI, along with Alamagan and Sarigan, with a substantial population of the endemic Slevin's skink (*Emoia slevini*).

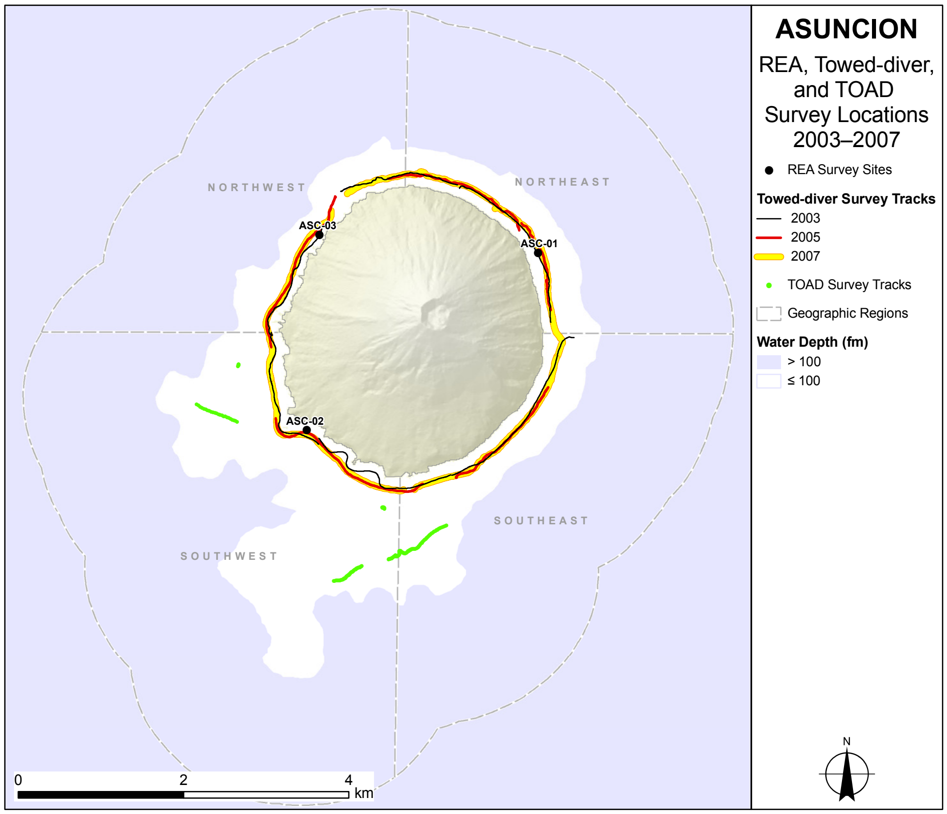
Because of Asuncion's isolated location and lack of inhabitants, local anthropogenic effects around this island likely are few. However, non-native species, including several species of plants and rats, reportedly have been introduced to this island (Pacific Protected Areas Database; U.S. Departement of Agriculture Forest Service 2008). Fishing activity within the CNMI tends to be focused around the southern islands of the Mariana Archipelago, with multiday fishing trips on the islands and banks south of Guguan (Western Pacific Fishery Management Council 2009).

Asuncion is part of the Marianas Trench Marine National Monument, formed by presidential proclamation in January 2009. This Marine National Monument includes 3 units: the Trench Unit, Islands Unit, and Vents Unit. The Islands Unit includes the waters and submerged lands of the islands of Asuncion, Maug, and Farallon de Pajaros.

15.2 Survey Effort

Biological, physical, and chemical observations collected under the Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP) have documented the conditions and processes influencing coral reef ecosystems around the island of Asuncion since 2003. The spatial reach and time frame of these survey efforts are discussed in this section. The disparate areas around this island often are exposed to different environmental conditions. To aid discussions of spatial patterns of ecological and oceanographic observations that appear throughout this chapter, 4 geographic regions around Asuncion are delineated in Figure 15.2a; wave exposure and breaks in survey locations were considered when defining these geographic regions. This figure also displays the locations of the Rapid Ecological Assessment (REA) surveys, towed-diver surveys, and towed optical assessment device (TOAD) surveys conducted around this island. Potential reef habitat is represented by a 100-fm contour shown in white on this map.

Figure 15.2a. Locations of the REA, towed-diver, and TOAD benthic surveys conducted around Asuncion during MARAMP 2003, 2005, and 2007. To aid discussion of spatial patterns, this map delineates 4 geographic regions: northeast, southeast, southwest, and northwest.



Benthic habitat mapping data were collected around Asuncion using a combination of acoustic and optical survey methods. MARAMP benthic habitat mapping surveys conducted in 2007 around Asuncion, Maug, Supply Reef, and Farallon de Pajaros with multibeam sonar covered a total area of 3856 km^2. Optical validation and habitat characterization were completed using towed-diver and TOAD surveys that documented live-hard-coral cover, sand cover, and habitat complexity. The results of these efforts are discussed in Section 15.3: "Benthic Habitat Mapping and Characterization."

Information on the condition, abundance, diversity, and distribution of biological communities around Asuncion was collected using REA, towed-diver, and TOAD surveys. The results of these surveys are reported in Sections 15.5–15.8: "Corals and Coral Disease," "Algae and Algal Disease," "Benthic Macroinvertebrates," and "Reef Fishes." The numbers of surveys conducted during MARAMP 2003, 2005, and 2007 are presented in Table 15.2a, along with their mean depths and total areas and length.

Table 15.2a. Numbers, mean depths (m), total areas (ha), and total length (km) of REA, towed-diver, and TOAD surveys conducted around Asuncion during MARAMP 2003, 2005, and 2007. REA survey information is provided for both fish and benthic surveys, the latter of which includes surveys of corals, algae, and macroinvertebrates.

Survey Type	Survey Detail	Year		
REA		**2003**	**2005**	**2007**
Fish	Number of Surveys	3	3	3
	Mean Depth (m)	13.8 (SD 2.3)	13.8 (SD 2.3)	13.8 (SD 2.3)
Benthic	Number of Surveys	3	3	3
	Mean Depth (m)	13.8 (SD 2.3)	13.8 (SD 2.3)	13.8 (SD 2.3)
Towed Diver		**2003**	**2005**	**2007**
	Number of Surveys	6	5	5
	Total Survey Area (ha)	11.1	8.8	11.2
	Mean Depth (m)	11.8 (SD 1)	14.9 (SD 1.6)	13.9 (SD 1.6)
TOAD		**2003**		
	Number of Surveys	5		
	Total Length (km)	1.84		

Spatial and temporal observations of key oceanographic and water-quality parameters influencing reef conditions around Asuncion were collected using (1) subsurface temperature recorders (STRs) designed for long-term observations of high-frequency variability of temperature, (2) closely spaced conductivity, temperature, and depth (CTD) profiles of the vertical structure of water properties, and (3) discrete water samples for nutrient and chlorophyll-*a* analyses. CTD casts were conducted during MARAMP 2003, 2005, and 2007, and water sampling was performed during MARAMP 2007 (see Chapter 2: "Methods and Operational Background," Section 2.3: "Oceanography and Water Quality"). A summary of deployed instruments and collection activities is provided in Table 15.2b. Results are discussed in Section: 15.4: "Oceanography and Water Quality."

Table 15.2b. Numbers of subsurface temperature recorders (STRs) deployed, shallow-water and deepwater CTD casts performed, and water samples collected around Asuncion during MARAMP 2003, 2005, and 2007. Shallow-water CTD casts and water samples were conducted from the surface to a 30-m depth, and deepwater casts were conducted to a 500-m depth. Deepwater CTD cast information is presented in Chapter 3: Archipelagic Comparisons.

Observation Type	Year						
Instruments	**2003**	**2005**		**2007**		**2009**	**Lost**
	Deployed	**Retrieved**	**Deployed**	**Retrieved**	**Deployed**	**Retrieved**	
STR	1	1	1	1	1	1	–
CTD Casts	**2003**	**2005**		**2007**			**Total**
Shallow-water Casts	8	–		12			20
Deepwater Casts	–	3		5			8
Water Samples		**2005**		**2007**			**Total**
		–		4			4

Towed-diver Surveys: Depths

Figures 15.2b and c illustrate the locations and depths of towed-diver-survey tracks around Asuncion and should be referenced when further examining results of towed-diver surveys from MARAMP 2003, 2005, and 2007.

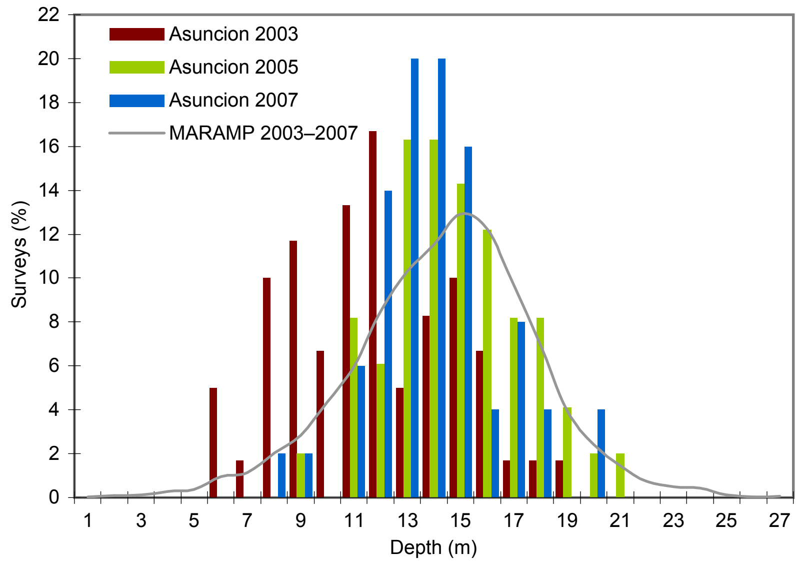


Figure 15.2b. Depth histogram plotted from mean depths of 5-min segments of towed-diver surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. Mean segment depths were derived from 5-s depth recordings. Segments for which no depth was recorded were excluded. The grey line represents average depth distribution for all towed-diver surveys conducted around the Mariana Archipelago during MARAMP 2003, 2005, and 2007.

During MARAMP 2003, 6 towed-diver surveys were conducted along the forereef slopes around Asuncion (Figs. 15.2b and c, top panel). The mean depth of all benthic survey segments was 11.8 m (SD 1), and the mean depths of individual surveys ranged from 10.2 m (SD 4.2) to 13 m (SD 4).

During MARAMP 2005, 5 towed-diver surveys were conducted along the forereef slopes around most of Asuncion (Figs. 15.2b and c, middle panel). The mean depth of all benthic survey segments was 14.9 m (SD 1.6), and the mean depths of individual surveys ranged from 12.7 m (SD 2.3) to 16.6 m (SD 3.5).

During MARAMP 2007, 5 towed-diver surveys were conducted along the forereef slopes around Asuncion (Figs. 15.2b and c, bottom panel). The mean depth of all benthic survey segments was 13.9 m (SD 1.6), and the mean depths of individual surveys ranged from 12.6 m (SD 2.3) to 16.6 m (SD 3.2).

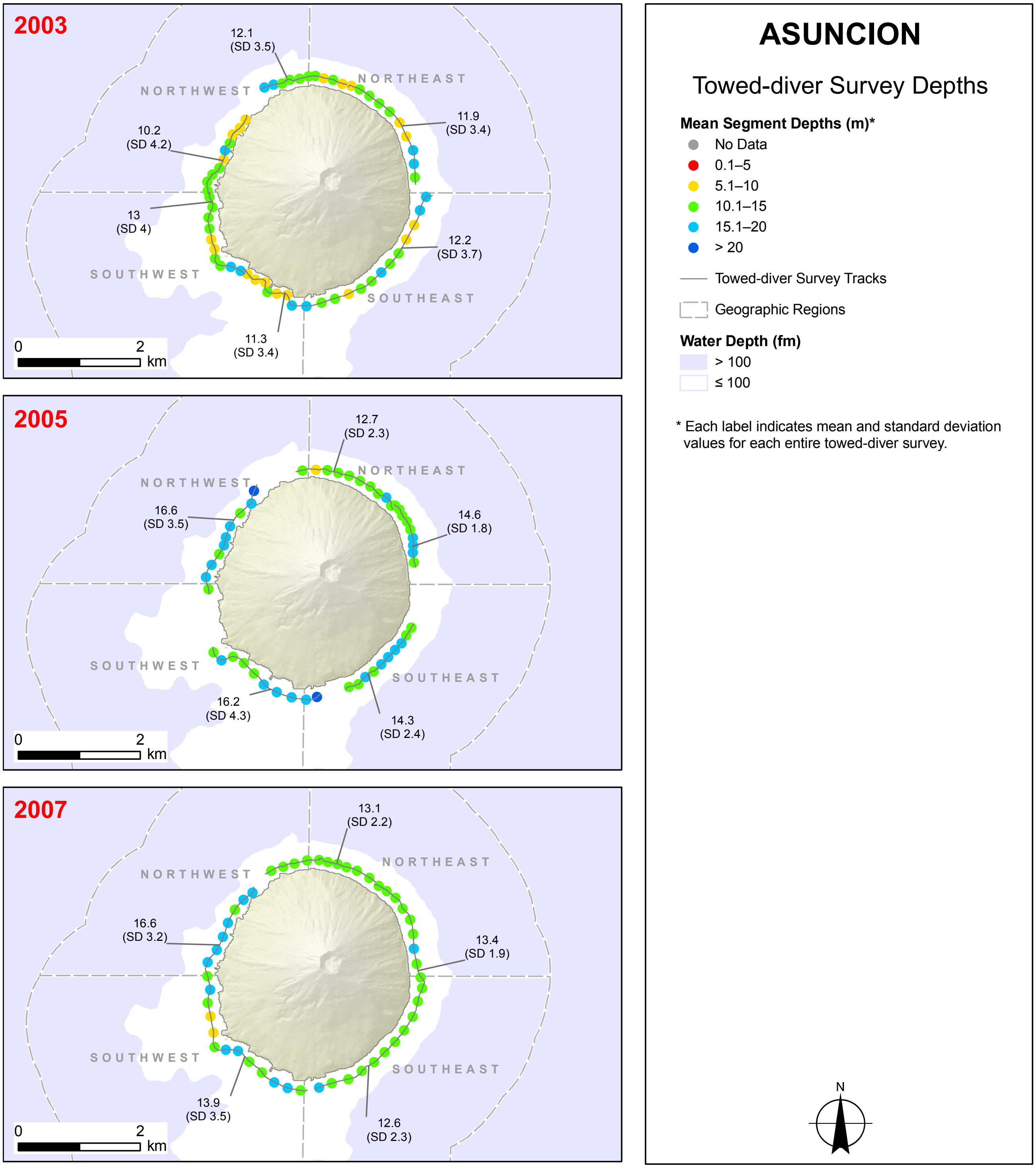


Figure 15.2c. Depths and tracks of towed-diver surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, 2007. Towed-diver-survey tracks are color coded by mean depth for each 5-min segment. A black-text label shows the mean depth (and standard deviation) for each entire towed-diver survey. Each depth represents the depth of the benthic towboard during each survey; towboards are maintained nominally 1 m above the benthic substrate.

15.3 Benthic Habitat Mapping and Characterization

Benthic habitat mapping and characterization surveys the around the island of Asuncion were conducted during MARAMP 2003, 2005, and 2007 using acoustic multibeam sonar, underwater video and still imagery, and towed-diver observations. Acoustic multibeam sonar mapping provided bathymetric and backscatter data products over the depth range of ~ 10–2300 m. Optical validation and benthic characterization, via diver observations and both video and still underwater imagery, were performed using towed-diver surveys and TOAD deployments conducted at depths of 2–120 m.

15.3.1 Acoustic Mapping

Multibeam acoustic bathymetry and backscatter imagery collected by the Coral Reef Ecosystem Division (CRED) around Asuncion, Maug, Supply Reef, and Farallon de Pajaros during MARAMP 2007 encompassed an area of 3856 km^2.

Low-resolution multibeam bathymetry data show the uniformly steep-sided volcanic cone that forms Asuncion (Fig. 15.3.1a, top panel). Data collected by CRED do not entirely cover the flanks of this volcano, extending only to depths of ~ 1300 m east and west of this island. However, data acquired during transits north and south of Asuncion reveal that the flanks continue to descend to ~ 2300 m before reaching deep plateaus that separate Asuncion from Maug, located 41 km northwest of this island, and Agrihan, located 100 km to the southeast. These low-resolution bathymetry data also reveal several canyon and ridge features on the southwestern flanks of Asuncion.

The limited low-resolution backscatter data acquired around Asuncion show numerous artifacts (Fig. 15.3.1a, bottom panel), such as sudden changes in backscatter intensity that do not appear to relate to the seabed topography. As discussed

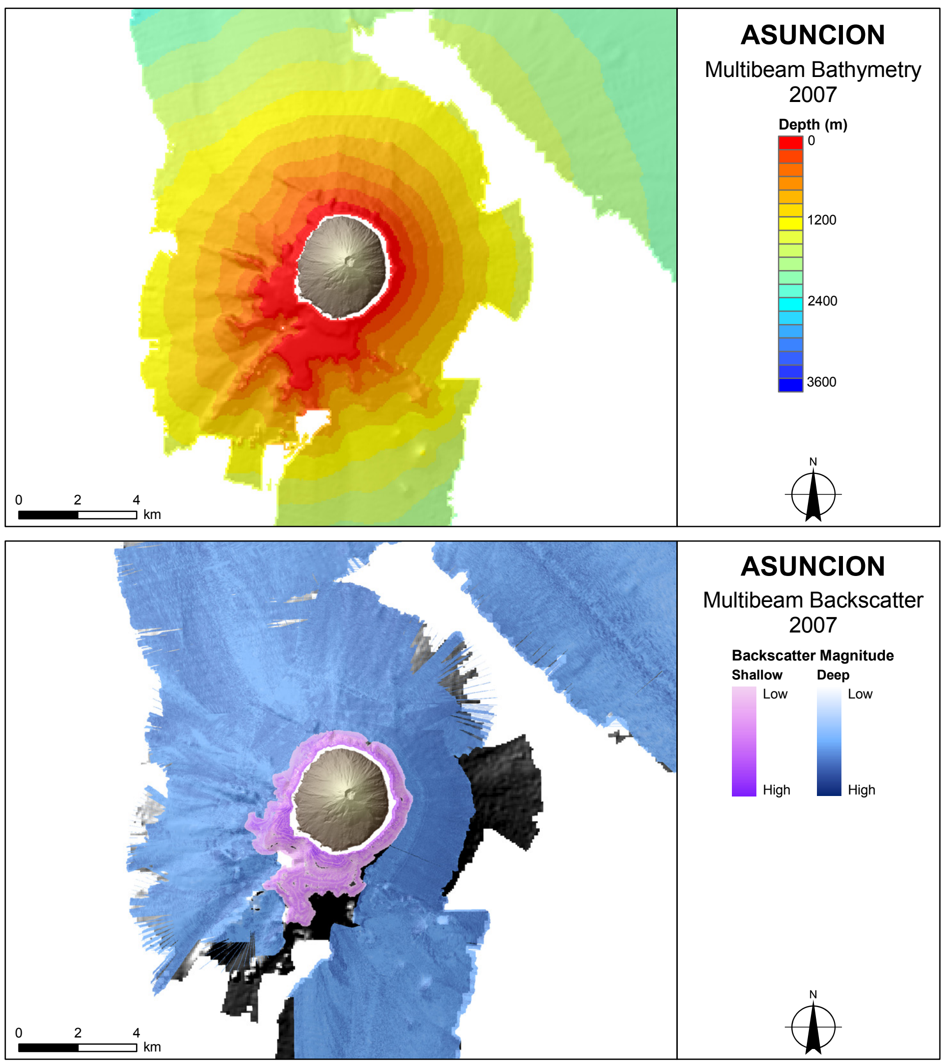


Figure 15.3.1a. Gridded (*top*) multibeam bathymetry (grid cell size: 60 m) and (*bottom*) backscatter (grid cell size: 5 m) collected around Asuncion during MARAMP 2007 at depths of 10–2300 m. Shallow-backscatter data (shown in purple) were collected using a 240-kHz Reson SeaBat 8101 ER sonar, and deep-backscatter data (shown in blue) were collected using a 30-kHz Kongsberg EM 300 sonar. Light shades represent low-intensity backscatter and may indicate acoustically absorbent substrates, such as unconsolidated sediment. Dark shades represent high-intensity backscatter and may indicate consolidated hard-bottom or coral substrates. Black areas are seen where backscatter data do not fully overlap bathymetry data.

in Chapter 2: “Methods and Operational Background”, Section 2.2.2: “Acoustic Mapping: Data Processing,” a number of factors aside from the acoustic character of the seabed can affect backscatter intensity. These factors include sonar settings during data acquisition and slope. It is likely that the exceptional steepness of the flanks of Asuncion influenced backscatter results, producing the artifacts noted at the beginning of this paragraph. Some patterns in these data appear less affected by artifacts, including the high-intensity backscatter recorded on the 3 ridges west of Asuncion with low-intensity backscatter recorded between them. These data suggest that exposed rock is present at or near the surface of these ridges and that soft sediments are present on the surrounding flanks.

High-resolution Multibeam Bathymetry and Derivatives

High-resolution multibeam data collected in nearshore (depths of 0–800 m) waters around Asuncion were combined into a grid with a 10-m resolution (Fig. 15.3.1b). These data allow for the identification of fine-scaled features. These high-resolution data were used to derive benthic maps showing slope (Fig. 15.3.1c), rugosity (Fig. 15.3.1d), and bathymetric position index (BPI) zones (Fig. 15.3.1e). Together, these maps provide layers of information to characterize the benthic habitats around Asuncion.

Within the northeast and much of the southeast regions, the seabed of Asuncion is classified as a slope zone. The crests and depressions shown at the inner and outer edge of the BPI map in these regions are artifacts caused by depth value comparisons of cells at the edge of the data set to adjacent cells that contain no data. Within these regions, the seabed is characterized by flanks with uniformly steep slope values (20°–30°), very little variation in topography, and moderate rugosity levels.

Northwest of Asuncion, the flanks of this volcano are very similar in character to those in the northeast region, apart from the 3 long ridges that extend along the length of this mapped area. These narrow ridges are characterized by steeply sloping (> 50°), high-rugosity sides.

South of Asuncion, the seabed topography is dominated by a large, low-rugosity shelf, which is highlighted as a flat zone in the BPI analysis. This shelf is composed of a number of terraces: a narrow terrace at ~ 30 m, a much larger shelf at 100–120 m that is ~ 1.5 km at its widest point, and a series of successively deeper narrow shelves. Numerous steep-sided ridges descend from the edge of the largest shelf, forming wide channels between ridges. These ridges and channels form the complex pattern of crests and depressions identified on the BPI analysis.

Southwest of Asuncion, a similar series of shelves are shown in the bathymetry, slope, and BPI maps, although these shelves are much less extensive than the previously described shelf south of this island. Again, a series of ridges and canyons fan out from these shelves with slopes > 50°. Below and between these ridges, the flanks of Asuncion are uniformly steep with moderate rugosity levels recorded. Like the larger shelf south of Asuncion, this shelf area is characterized by low levels of rugosity, whereas ridge features have very high rugosity values.

In the shallowest waters surveyed, the BPI analysis identifies reef crests. However, this classification is likely an artifact of the methodology, since no data are available for immediately inshore areas and no comparison can be made to the innermost cells of the grid. Instead, these areas probably should be characterized as slopes.

Figure 15.3.1b. High-resolution multibeam bathymetry collected around Asuncion during MARAMP 2007. This 10-m bathymetry grid, clipped at 800 m, is used as the basis for slope, rugosity, and BPI derivatives.

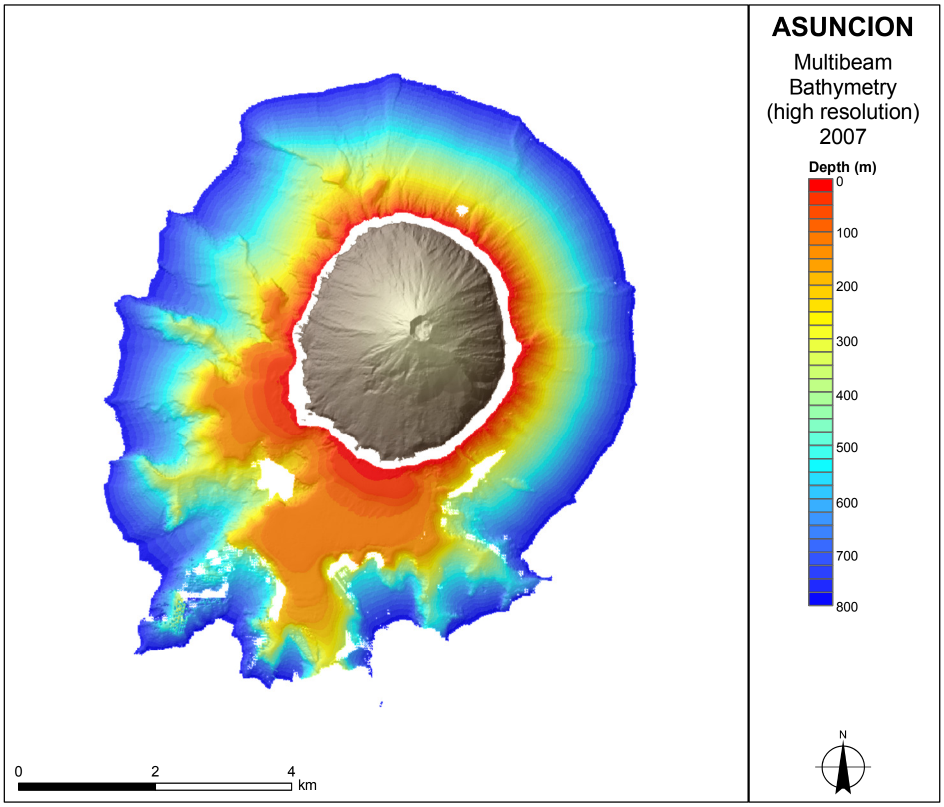
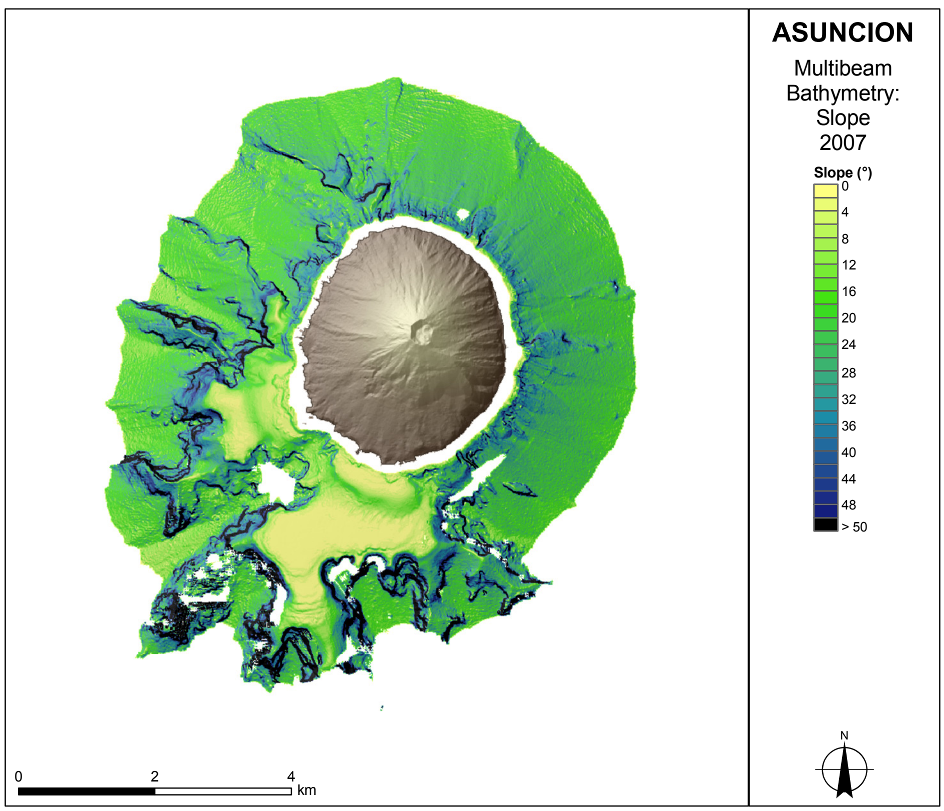


Figure 15.3.1c. Slope (°) of 10-m bathymetric grid around Asuncion. Derived from data collected in 2007, this map reflects the maximum rate of change in elevation between neighboring cells.



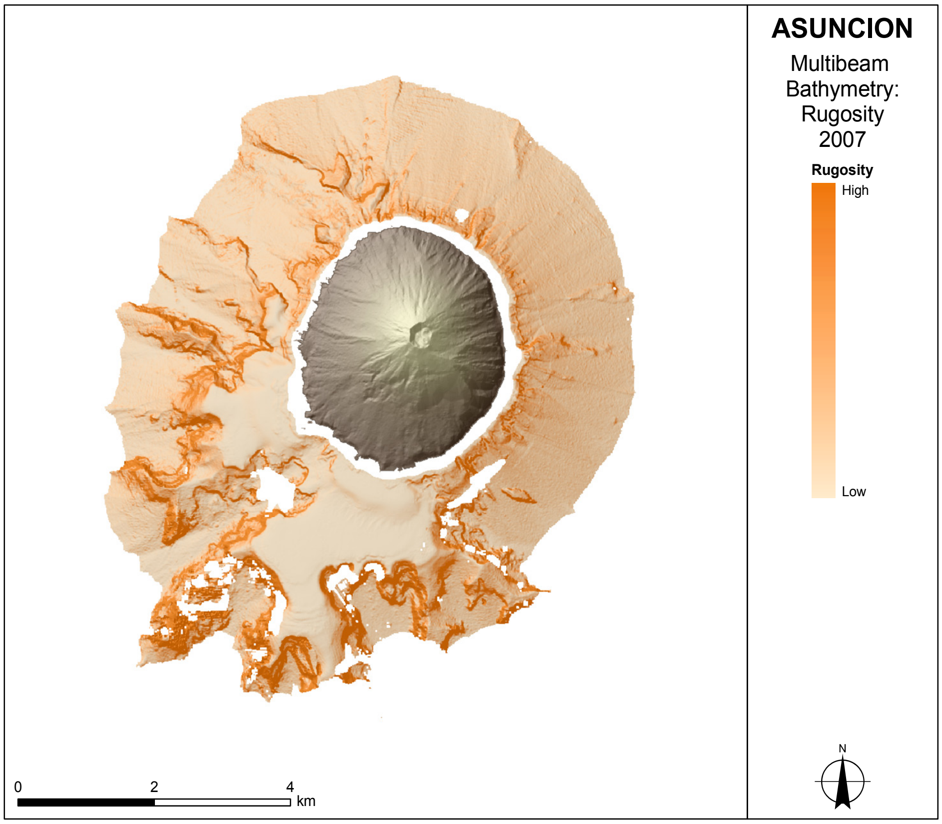


Figure 15.3.1d. Rugosity of 10-m bathymetric grid around Asuncion. Derived from data collected in 2007, these rugosity values are a measure of the ratio of surface area to planimetric area within a given cell's neighborhood and indicate topographic roughness.

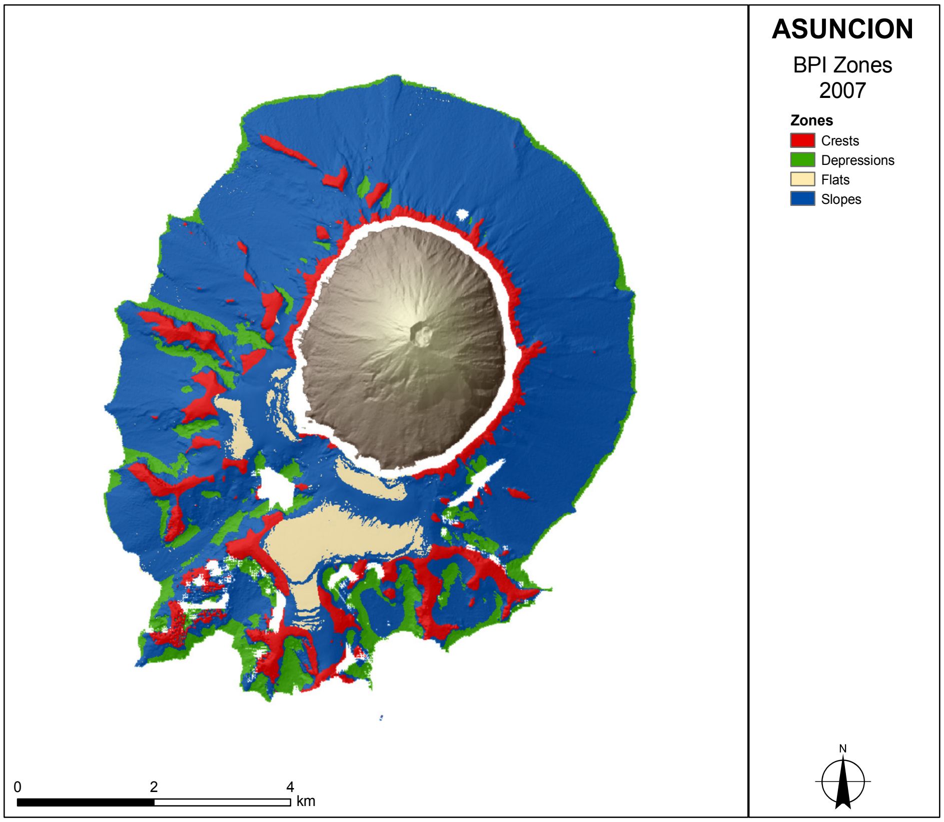


Figure 15.3.1e. BPI zones of 10-m bathymetric grid around Asuncion derived from data collected in 2007. BPI is a second-order derivative of bathymetry that evaluates elevation differences between a focal point and the mean elevation of the surrounding cells within a user-defined circle. Four BPI Zones—crests, depressions, flats, and slopes—were used in this analysis.

High-resolution Multibeam Backscatter and Derivatives

High-resolution backscatter data were acquired around Asuncion using a 240-kHz Reson SeaBat 8101 ER sonar. These data were affected by several quality issues. Data gaps were observed around much of this island between the deepest swath and the relatively shallow swaths. Furthermore, backscatter values within the shallow part of the outer swath were higher than within the deep part. This artifact can be caused by steep slopes affecting the intensity of the backscatter return. These backscatter data also may have been affected by sonar settings and sea conditions during data acquisition or other factors discussed in more detail in Chapter 2: "Methods and Operational Background," Section 2.2.2: "Acoustic Mapping: Data Processing," These artifacts were exacerbated in the hard–soft analysis, resulting in false classification of areas because of data quality issues and did not truly reflect the nature of the substrate. Therefore, no hard–soft maps are presented for Asuncion.

Despite these data quality issues, the high-resolution backscatter data acquired around Asuncion do reveal some information about the nature of seabed substrates. The highest backscatter values were recorded on the shallowest of the shelves south and southwest of this island (Fig. 15.3.1f). In contrast, lower backscatter values were recorded on the deeper shelves. These backscatter data and low-rugosity values suggest that these shelves are characterized by soft sediments. Between these 2 shelf areas and east of the southern shelf, backscatter values of very low intensity were recorded, suggesting that soft sediments may accumulate within these wide channels separating the 2 shelves. Elsewhere around Asuncion, high-backscatter values were recorded on shallow seabed areas and lower backscatter values were recorded on the steeply sloping flanks.

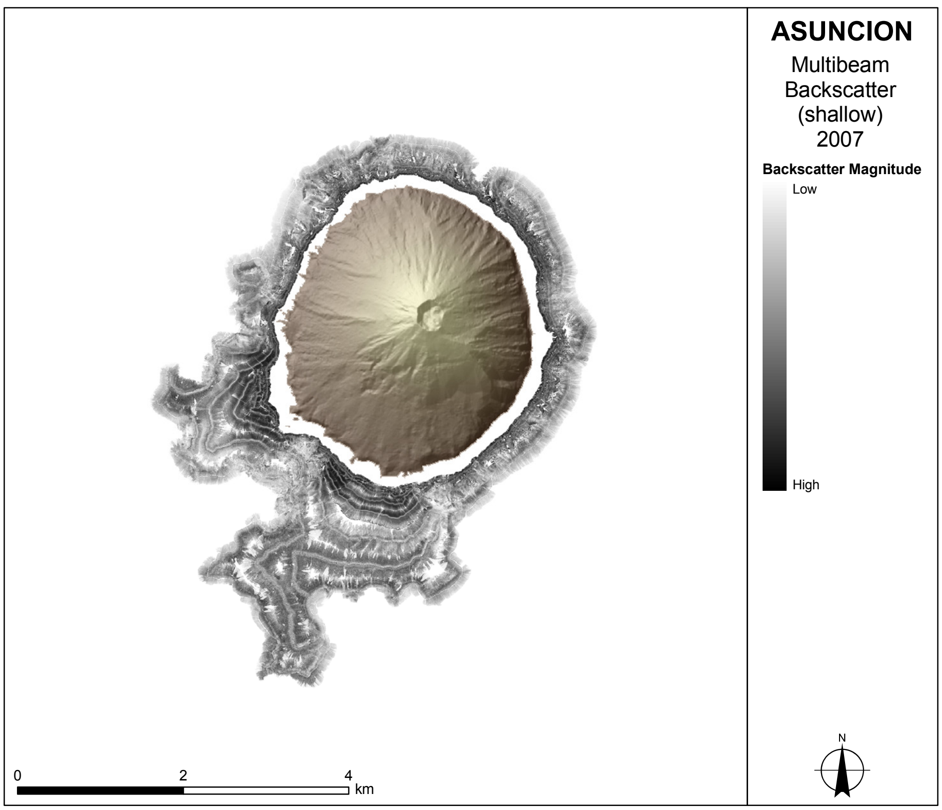


Figure 15.3.1f. Gridded, high-resolution, multibeam backscatter data (grid cell size: 1 m) collected around Asuncion during MARAMP 2007. Light shades represent low-intensity backscatter and may indicate acoustically absorbent substrates. Dark shades represent high-intensity backscatter and may indicate consolidated hard-bottom and coral substrates.

15.3.2 Optical Validation

During MARAMP 2003, 5 TOAD optical-validation surveys were conducted around Asuncion at depths of 30–120 m. Subsequent analyses of video acquired from these surveys provided estimates of the percentages of sand cover and live coral cover (Fig. 15.3.3a).

Covering a distance of 31 km at depths of 6–20 m, 16 towed-diver optical-validation surveys of forereef habitats, were conducted around Asuncion during MARAMP 2003, 2005, and 2007. At 5-min intervals within each survey, divers recorded percentages of sand cover, live-hard-coral cover, and habitat complexity using a 6-level categorical scale from low to very high (Fig. 15.3.3a).

15.3.3 Habitat Characterization

Sand cover, habitat complexity, and live coral cover around Asuncion are discussed in this section. These descriptions are discussed with reference to the 4 geographic regions around Asuncion.

In the northeast region, based on towed-diver surveys conducted during MARAMP 2003, 2005, and 2007, sand cover was predominantly < 20% (Fig. 15.3.3a, top panel), although a small patch of higher sand cover (20.1%–30%) was observed

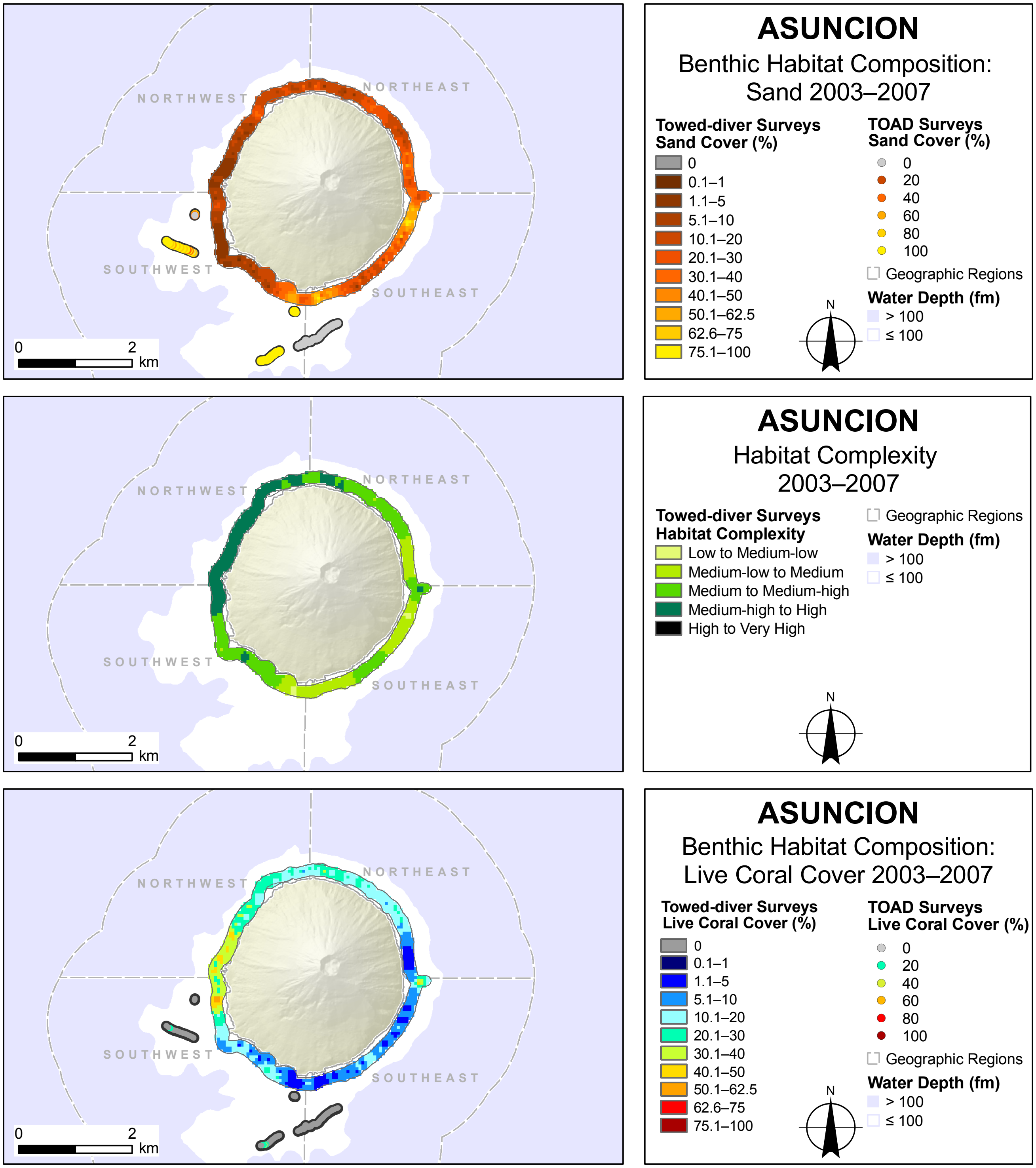


Figure 15.3.3a. Observations of (*top*) sand cover (%), (*middle*) benthic habitat complexity, and (*bottom*) live-hard-coral cover (%) from towed-diver surveys of forereef habitats conducted and analysis of TOAD video collected around Asuncion during MARAMP 2003, 2005, and 2007.

where 2 deep channels cut into the flanks of this volcano. Habitats of medium to medium-high complexity were observed in much of this region (Fig. 15.3.3a, middle panel). In this area, live coral cover from towed-diver surveys was < 20% (Fig. 15.3.3a, bottom panel). Collectively, these observations suggest that habitats in this region predominantly are hard substrates that supported low levels of live coral cover. Towed divers described habitats in this area as steeply sloping, irregular, rocky reef and boulders. In the southern part of this region, moderately high (20.1%–50%) sand cover and low (< 10%) live coral cover were observed on a patch of medium-low to medium complexity.

Southeast and south of Asuncion, habitat complexity from towed-diver surveys ranged from low to medium-high. Two areas of medium-low to medium habitat complexity had sandy habitats with sand cover of 30.1%–100% and live coral cover < 10%. The northernmost of these 2 sandy areas had boulders on sand. The southern sand patch, located on an extensive shelf area, had habitats described as spur-and-groove formations, sand flat, and boulders on sand. Located between these 2 sandy areas, hard substrates with < 30% sand cover and < 20% live coral cover were found for a patch of medium to medium-high complexity.

Two TOAD surveys conducted south of Asuncion, a short survey on the shallow shelf area (30-m depth) and a longer survey on the deep shelf (depths of 105–115 m), suggested a seabed characterized by 100% sand cover. On this deep shelf, analysis of several frames of video taken at a depth of 113 m suggested that live coral cover was 20.1%–40%, although no additional cover of live corals was observed in TOAD video footage acquired in this area. An additional TOAD survey conducted on this deep shelf at the same depth found no sand cover (Fig. 15.3.3a, top panel); however, analyses of this video classified the observed substrate as "unconsolidated," a term used to describe substrates where it is difficult to distinguish between sand and mud in video footage. Thus, the seabed in this area also was composed of some kind of soft sediments. In this same TOAD survey, an additional feature of interest was the discovery of a dense aggregation of sea pens (order: Pennatulacea), extending over a linear distance of at least 1.4 km and occurring at depths of 70–120 m (Fig. 15.3.3b). Aggregations were recorded standing as high as ~ 30 cm, and they occurred on a soft substrate, possibly composed of basaltic sand. Sea pens are most commonly observed at night (Allen and Steele 2002), and some species are known to form dense aggregations (Gotshall 1994). However, despite extensive nighttime surveying with the TOAD at similar depths around other islands of the CNMI, high numbers of sea pens were not observed elsewhere. Similarly, extensive nighttime surveying in the Hawaiian Archipelago and American Samoa has not revealed such aggregations of sea pens, making their occurrence at Asuncion an uncommon, if not unique, occurrence.

Near the seaward end of the southernmost TOAD survey, where many sea pens were observed, a decline in density of sea pens at a depth of 120 m was associated with the occurrence of a 100-m-long patch of hard corals. Both corals and sea pens were observed near the eastern side of a steep-sided ledge that extends southward from Asuncion and rises abruptly from

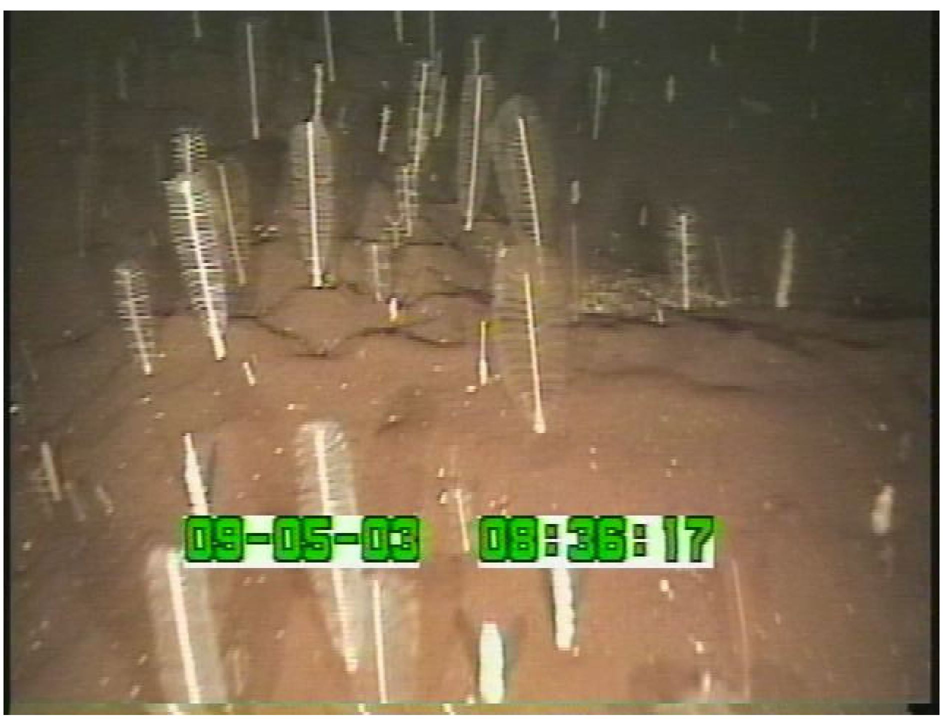


Figure 15.3.3b. Sea pens observed in TOAD video footage acquired south of Asuncion at depths of 70–120 m.

the surrounding seafloor at a depth of ~ 600 m (Fig. 15.3.1b). Strong currents were encountered during TOAD surveys, and persistent strong currents sweeping over the ledge may possibly enhance the atypically high density of benthic life in this area.

Southwest of Asuncion, an area characterized by live coral cover of 5.1%–20% and low sand cover of 1.1%–20%, based on towed-diver surveys. In this area, habitat of medium to medium-high complexity was described as ridges, boulders, continuous reef, and walls.

In the north part of the southwest region and over much of the northwest region, medium-high to high levels of habitat complexity were recorded during towed-diver surveys in an area where sand cover was generally < 20%. This area of spur-and-groove habitat supported the highest level of live coral cover seen around Asuncion, with interpolated coral cover of ~ 30.1%–60%. On the shelf below, analyses of TOAD video footage collected at depths of 55–110 m suggested a seabed characterized by high sand cover and very low live coral cover—with only one analyzed video frame showing live coral cover of 20%. A second TOAD survey was conducted at a depth of 50 m. This short survey revealed patches of high sand cover but no live coral cover.

15.4 Oceanography and Water Quality

15.4.1 Hydrographic Data

2003 Spatial Surveys

During MARAMP 2003, 8 shallow-water conductivity, temperature, and depth (CTD) casts were conducted in nearshore waters around the island of Asuncion on September 5. Temperature, salinity, density, and beam transmission values varied both spatially and vertically around this island (Figs. 15.4.1a and b). Spatial comparisons of water properties at a depth of 10 m suggest small differences in temperature (0.2°C), salinity (0.2 psu), density (0.2 kg m^{-3}), and beam transmission (< 0.2%) values; however, recorded salinity levels were higher around the western half of this island (casts 1–2 and 7–8) than around the eastern half (casts 3–6; Fig. 15.4.1a). Vertical comparisons of CTD profiles reveal intraisland differences in stratification. Well-mixed waters (casts 3–6) were recorded in the northeast and southeast regions, while highly stratified waters were observed in the northwest and southwest regions (casts 1–2 and 7–8). Moderate ranges in temperature (0.8°C) salinity (0.3 psu), and density (0.5 kg m^{-3}) were observed in the stratified regions and were greater than the values recorded in the areas with well-mixed waters (Fig. 15.4.1b). The observed stratification differences around Asuncion are likely a result of enhanced mixing on the windward (east) side and surface heating of the upper water column on the leeward side.

2007 Spatial Surveys

During MARAMP 2007, 12 shallow-water CTD casts were conducted in nearshore waters around Asuncion on June 4. Temperature, salinity, density, and beam transmission values varied both spatially and vertically around this island (Figs. 15.4.1c and d). Spatial comparisons of water properties at a depth of 10 m suggest variability in temperature around Asuncion with cold waters observed in the northeast region and recorded intraisland differences as large as 1.4°C (Fig. 15.4.1c). Vertical comparisons of CTD profiles reveal highly stratified waters with a substantial range in water temperature (3.9°C) and broad ranges in salinity (0.5 psu), density (1.2 kg m^{-3}) and beam transmission (5.7%) values (Fig. 15.4.1d). Cold water intrusions of ~ 26°C originated from depths > 30 m at all CTD cast locations. The large ranges in physical oceanographic conditions at Asuncion can be attributed to localized upwelling of subsurface water, although the physical mechanism driving that upwelling cannot be determined without additional data.

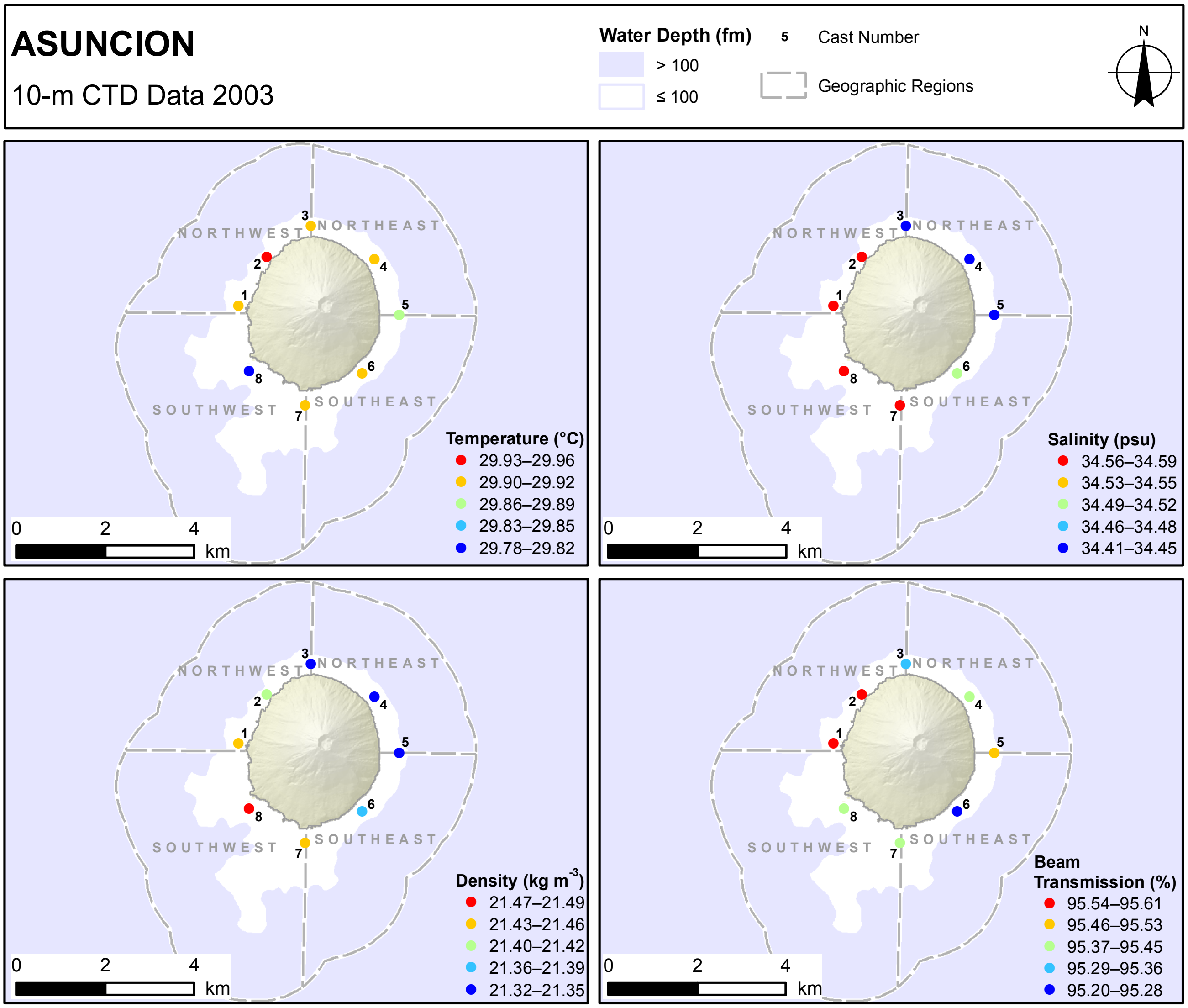


Figure 15.4.1a. Values of *(top left*) water temperature, (*top right*) salinity, (*bottom left*) density, and (*bottom right)* beam transmission at a 10-m depth from shallow-water CTD casts around Asuncion on September 5 during MARAMP 2003.

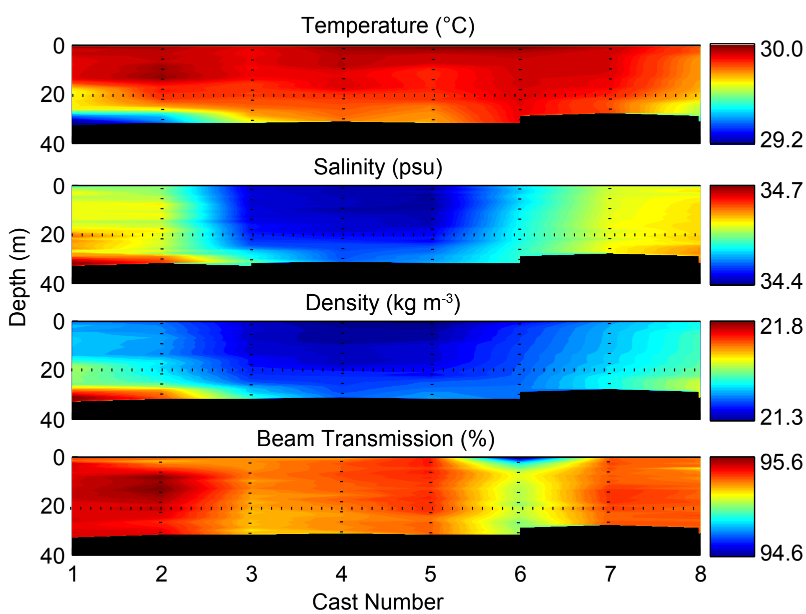


Figure 15.4.1b. Shallow-water CTD cast profiles to a 30-m depth around Asuncion on September 5 during MARAMP 2003, including temperature (°C), salinity (psu), density (kg m^{-3}), and beam transmission (%). Profiles, shown sequentially in a left-to-right direction in this graph, correspond to cast locations that are numbered sequentially 1–8, in a clockwise direction around Asuncion. For cast locations and numbers around Asuncion in 2003, see Figure 15.4.1a.

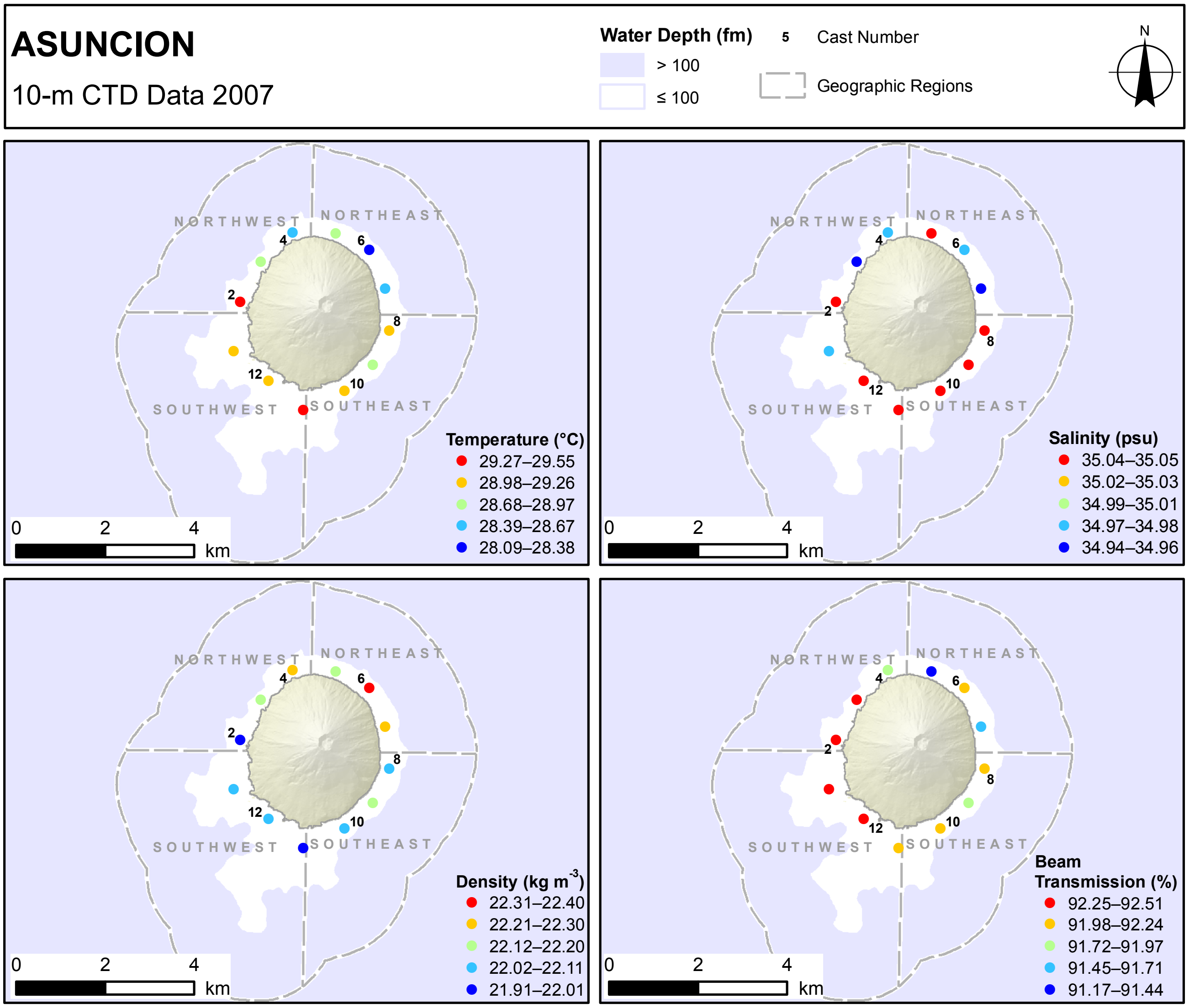


Figure 15.4.1c. Values of (*top left*) water temperature, (*top right*) salinity, (*bottom left*) density, and (*bottom right*) beam transmission at a 10-m depth from shallow-water CTD casts around Asuncion on June 4 during MARAMP 2007.

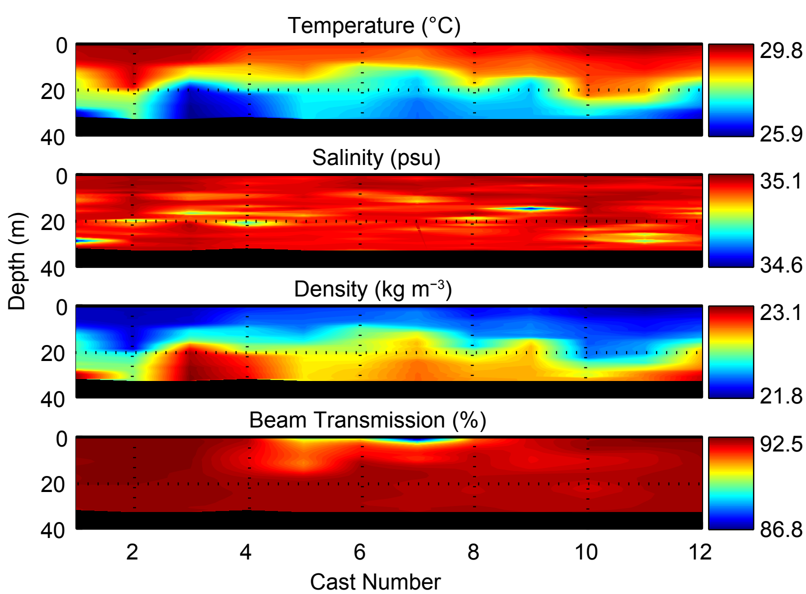


Figure 15.4.1d. Shallow-water CTD cast profiles to a 30-m depth around Asuncion on June 4 during MARAMP 2007, including temperature (°C), salinity (psu), density (kg m^{-3}), and beam transmission (%). Profiles, shown sequentially in a left-to-right direction in this graph, correspond to cast locations that are numbered sequentially 1–12, in a clockwise direction around Asuncion. For cast locations and numbers around this island in 2007, see Figure 15.4.1c.

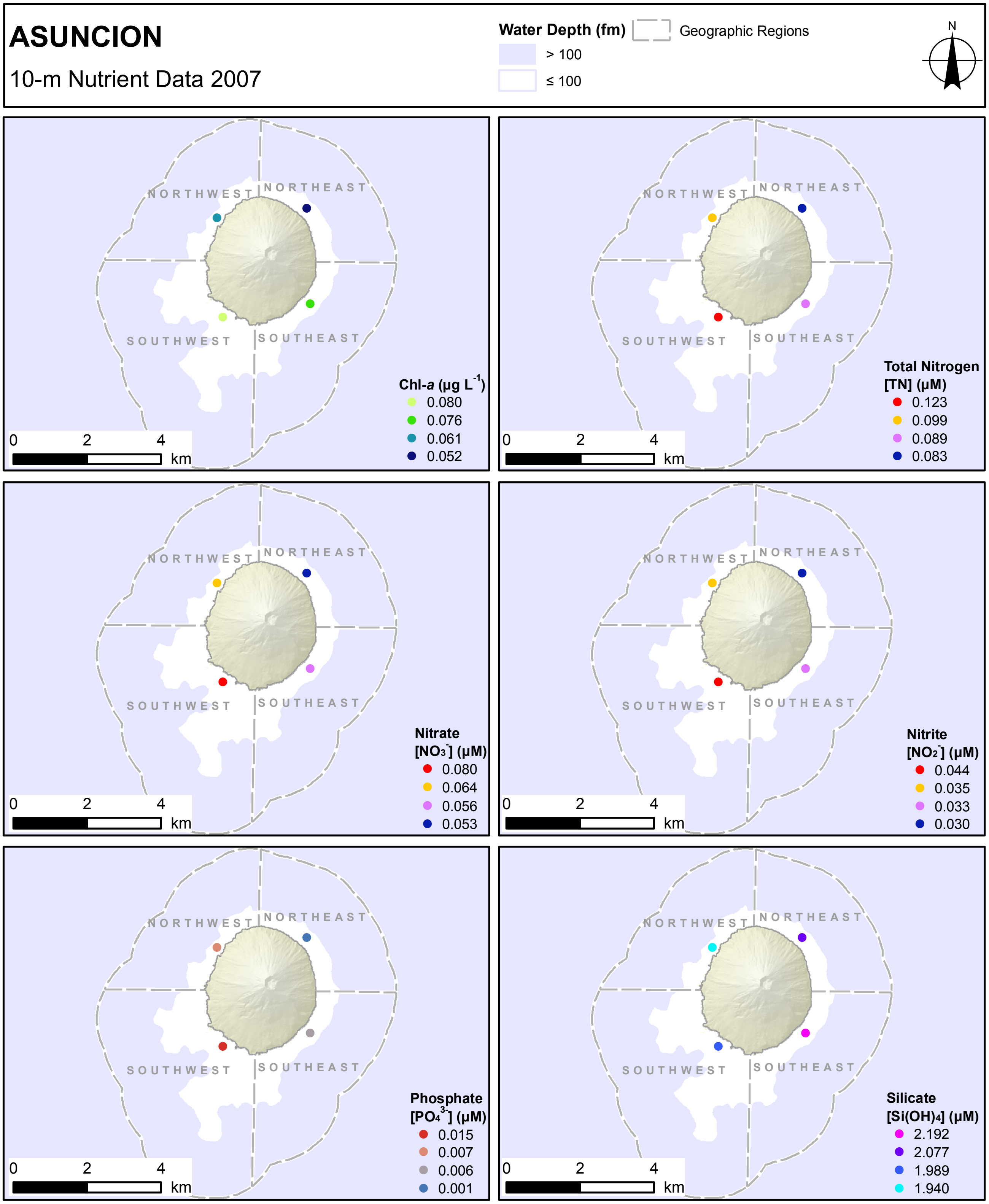


Figure 15.4.1e. Concentrations of (*top left*) Chl-*a*, (*top right*) total nitrogen, (*middle left*) nitrate, (*middle right*) nitrite, (*bottom left*) phosphate, and (*bottom right*) silicate at a 10-m depth, from water samples collected at Asuncion on June 4 during MARAMP 2007.

Water samples were collected in concert with shallow-water CTD casts at 4 select locations at Asuncion in 2007 to assess water-quality conditions. The following ranges of measured parameters were recorded: chlorophyll-*a* (Chl-*a*), 0.05–0.08 µg L^{-1}; total nitrogen (TN), 0.08–0.12 µM; nitrate (NO_3^-), 0.05–0.08 µM; nitrite (NO_2^-), 0.03–0.04 µM; phosphate (PO_4^{3-}), 0–0.02 µM; and silicate [$Si(OH)_4$], 1.94–2.2 µM. Water-quality parameters generally were observed at the relatively low levels typical of the Western Pacific Warm Pool's oligotrophic, oceanic surface layers. The greatest values for most parameters measured were recorded in the southwest region, except for silicate, which was highest in the southeast region (Fig. 15.4.1e).

Temporal Comparison

Temporal comparisons of shallow-water CTD data collected around Asuncion during MARAMP 2003 and 2007 suggest a dynamic physical oceanographic environment. During MARAMP 2003, spatial variability was observed around Asuncion, with the waters surrounding the western half of this island highly stratified and waters surrounding the eastern half well mixed. CTD profiles collected during MARAMP 2007 reported highly stratified waters around this entire island, and the distinct intraisland differences seen in 2003 were not recorded. Cold water intrusions of ~ 26°C (or ~ 3.9°C colder than surface waters) originating from depths below 30 m were recorded in vertical profiles at all CTD cast locations in 2007, possibly a result of upwelling or internal tide activity. Data were not collected with respect to a specific tidal cycle, which could be a source of oceanographic variability. Likewise, hydrographic variation between MARAMP survey years is likely a result of differences in season. MARAMP 2007 occurred in June, and MARAMP 2003 occurred in September. This change was made to avoid the typhoon season and reduce the probability of weather disruptions.

15.4.2 Time-series Observations

Between MARAMP 2003 and 2007, subsurface temperature recorders (STR) were deployed at a single location at Asuncion to collect time-series observations of a key oceanographic parameter (Fig. 15.4.2a). The location, depth, time frame, and other details about these deployments are provided in Figures 15.4.2a and b.

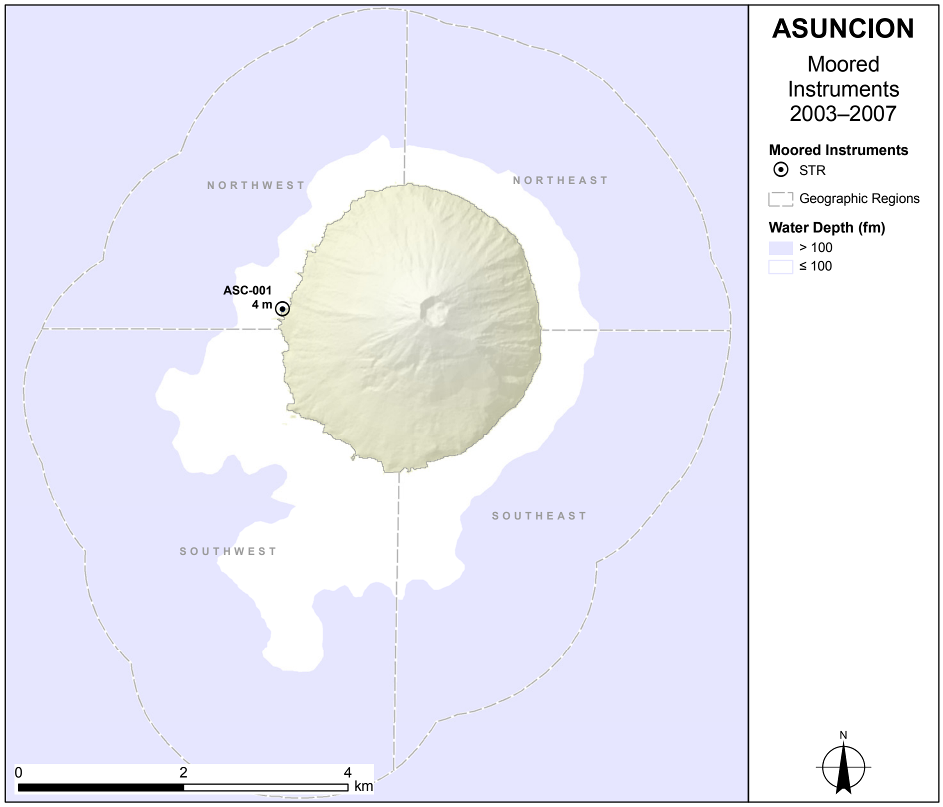


Figure 15.4.2a. Location and depth of the STRs deployed at Asuncion during MARAMP 2003, 2005, and 2007.

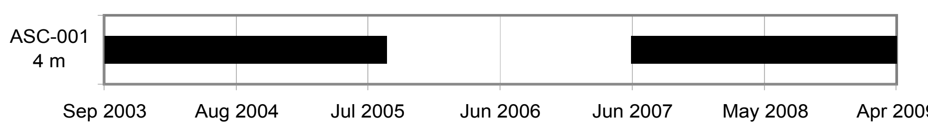


Figure 15.4.2b. Deployment timeline and depth of the STRs moored at Asuncion during the period from September 2003 to April 2009. A solid bar indicates the period for which data were collected by a series of STRs deployed and retrieved at a mooring site. For more information about deployments and retrievals, see Table 15.2b in Section 15.2: "Survey Effort."

Temperature data from STRs deployed at a single location at a depth of 4 m in the northwest region show seasonal temperature variability of ~ 4°C between summer and winter months (Fig. 15.4.2c). Water temperatures reached ~ 30°C during the months of June–October and fell to a low of ~ 25.5°C during the months of January–May. Additionally, high-frequency (~ 12-h return periods) temperature fluctuations of 1°C–3°C were recorded in spring and summer 2004. During a period in May 2004, an event resulted in water temperatures falling to 24°C. Internal tides are generated when tidal currents interact with steep subsurface topography, resulting in high-frequency variability in temperature, salinity, dissolved nutrients, and suspended particle concentrations that differ significantly from shallow reefs to deep slopes. Although more research and additional data are needed to properly ascertain the nature of these signals, the observed rapid temperature changes likely were the result of internal tides causing vertical displacements of the background stratification at mooring site ASC-001.

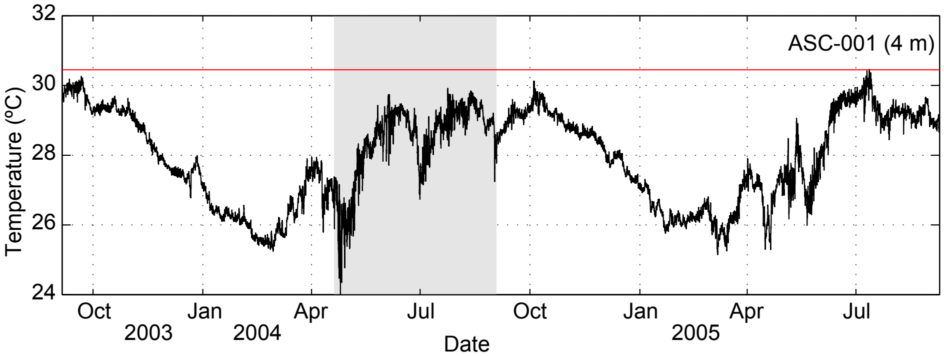


Figure 15.4.2c. Time-series observations of temperature over the period between September 2003 and September 2005 collected from 1 STR mooring site at a depth of 4 m (see Figure 15.4.2a for mooring location). The red line indicates the coral bleaching threshold, which is defined as 1°C above the monthly maximum climatological mean. A grey background indicates a period of high-frequency variability that likely resulted from internal tide activity.

15.4.3 Wave Watch III Climatology

Seasonal wave climatology for Asuncion was derived using the NOAA Wave Watch III model for the period of January 1997 to May 2008, and seasons were selected to elucidate waves generated by typhoons, which most frequently occur during the period of August–December (Fig. 15.4.3a). In terms of consistency, the wave regime during this period was dominated by trade wind swells characterized by frequent (> 20 d per season), relatively low-period (8–10 s), relatively small (2–3 m) wave events originating from the east (90°). Superimposed with these short-period swells were large (> 4 m), long-period (12–16 s) wave events principally from the south (180°), although they could originate from a broad directional source (120°–200°). These large, episodic waves primarily were generated via typhoons and occurred on annual to interannual time scales. Additionally, infrequent (~ 5 d per season), long-period (12–14 s) swells with moderate wave heights (2.5–3.5 m) occurred from the southwest (210°–250°) and probably were associated with episodic storms. Similar to the wave regime during typhoon season, the wave climate during the period of February–June (outside the typhoon season) also was characterized by frequent (> 30 d per season) and low-period (~ 8 s) trade-wind swells with relatively small wave heights (~ 2 m) originating from the east. Infrequent (< 10 d per season), long-period (12–14 s) swells with slightly larger wave heights (~ 3 m) also occurred during this period and originated from the northwest (330°).

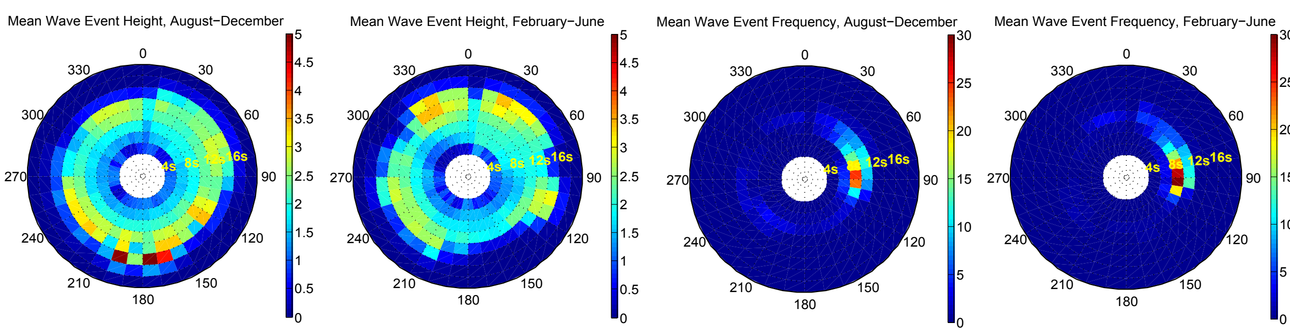


Figure 15.4.3a. NOAA Wave Watch III directional wave climatology for Asuncion from January 1997 to May 2008. This climatology was created by binning (6 times daily) significant wave height, dominant period, and dominant direction from a box (1° × 1°) centered on Asuncion (19° N, 145° E). Mean significant wave height (*far left and left*) for all observations in each directional and frequency bin from August to December (typhoon season) and from February to June. The transition months of January and July are omitted for clarity. Mean number of days (*right and far right*) that conditions in each directional and frequency bin occurred in each season; for example, if the color indicates 30, then, on average, the condition occurred during 30 of the 150 days of that season.

15.5 Corals and Coral Disease

15.5.1 Coral Surveys

Coral Cover and Colony Density

From MARAMP 2003 towed-diver surveys, mean cover of live hard corals on forereef habitats around the island of Asuncion was 18% (SE 1.9). Coral cover was highest along the west coast with a mean of 40% for 12 survey segments (Fig. 15.5.1a, top panel).

From MARAMP 2005 towed-diver surveys, mean cover of live hard corals on forereef habitats around Asuncion was 16% (SE 2.3). Similar to survey results from 2003, coral cover was highest along the west coast with a mean of 43% for 8 segments (Fig. 15.5.1a, middle panel). Towed divers during MARAMP 2005 recorded estimates of stressed-coral cover, including corals that were fully bleached (white), pale or discolored, malformed, or stricken with tumors (see Chapter 2: "Methods and Operational Background," Section 2.4.5, "Corals and Coral Disease"). Overall, 0.2% (SE 0.1) of coral cover observed on forereef habitats appeared stressed.

From MARAMP 2007 towed-diver surveys, mean cover of live hard corals on forereef habitats around Asuncion was 16% (SE 1.3). Again, coral cover was highest along the west coast with a mean of 29% over 9 segments (Fig. 15.5.1a, bottom panel). Overall, 2% (SE 0.4) of coral cover observed on forereef habitats appeared stressed; only 1 segment exhibited a high level (5%–10%) of stressed-coral cover (Fig. 15.5.1a, bottom panel). Predation by crown-of-thorns seastars (*Acanthaster planci*) was noted during this 1 segment in the southwest region, and lower levels of predation by crown-of-thorns seastars (COTS) were recorded in other survey areas in the southwest and northwest regions.

During MARAMP 2003, 3 REA benthic surveys using the quadrat method on forereef habitats at Asuncion documented 288 coral colonies within a total survey area of 11.25 m^2. Site-specific colony density ranged from 18.4 to 35.2 colonies m^{-2} with an overall sample mean of 25.6 colonies m^{-2} (SE 5). The highest colony density was recorded at REA site ASC-03 in the northwest region, and the lowest colony density was observed at ASC-02 in the southwest region (Fig. 15.5.1b, top panel).

During MARAMP 2005, 3 REA benthic surveys using the quadrat method on forereef habitats at Asuncion documented 515 coral colonies within a total survey area of 12 m^2. Site-specific colony density ranged from 37.8 to 48 colonies m^{-2} with an overall sample mean of 42.9 colonies m^{-2} (SE 3). The highest colony density was recorded at ASC-03 in the northwest region, and the lowest colony density was observed at ASC-02 in the southwest region (Fig. 15.5.1b, middle panel).

During MARAMP 2007, 3 REA benthic surveys using the line-point-intercept method were conducted on forereef habitats at Asuncion. Site-specific estimates of live-hard-coral cover from these surveys ranged from 8.8% to 25.5% with an overall sample mean of 15.7% (SE 5). Coral cover was highest at ASC-03 in the northwest region and lowest at ASC-01 in the northeast region (Fig. 15.5.1b, bottom panel).

During MARAMP 2007, 3 REA benthic surveys using the quadrat method on forereef habitats at Asuncion documented 636 coral colonies within a total survey area of 12 m^2. Site-specific colony density ranged from 52 to 53.8 colonies m^{-2} with an overall sample mean of 53 colonies m^{-2} (SE 0.5). Coral-colony density was similar at all 3 sites with values slightly higher than the colony densities observed at these sites in previous MARAMP survey years (Fig. 15.5.1b, bottom panel).

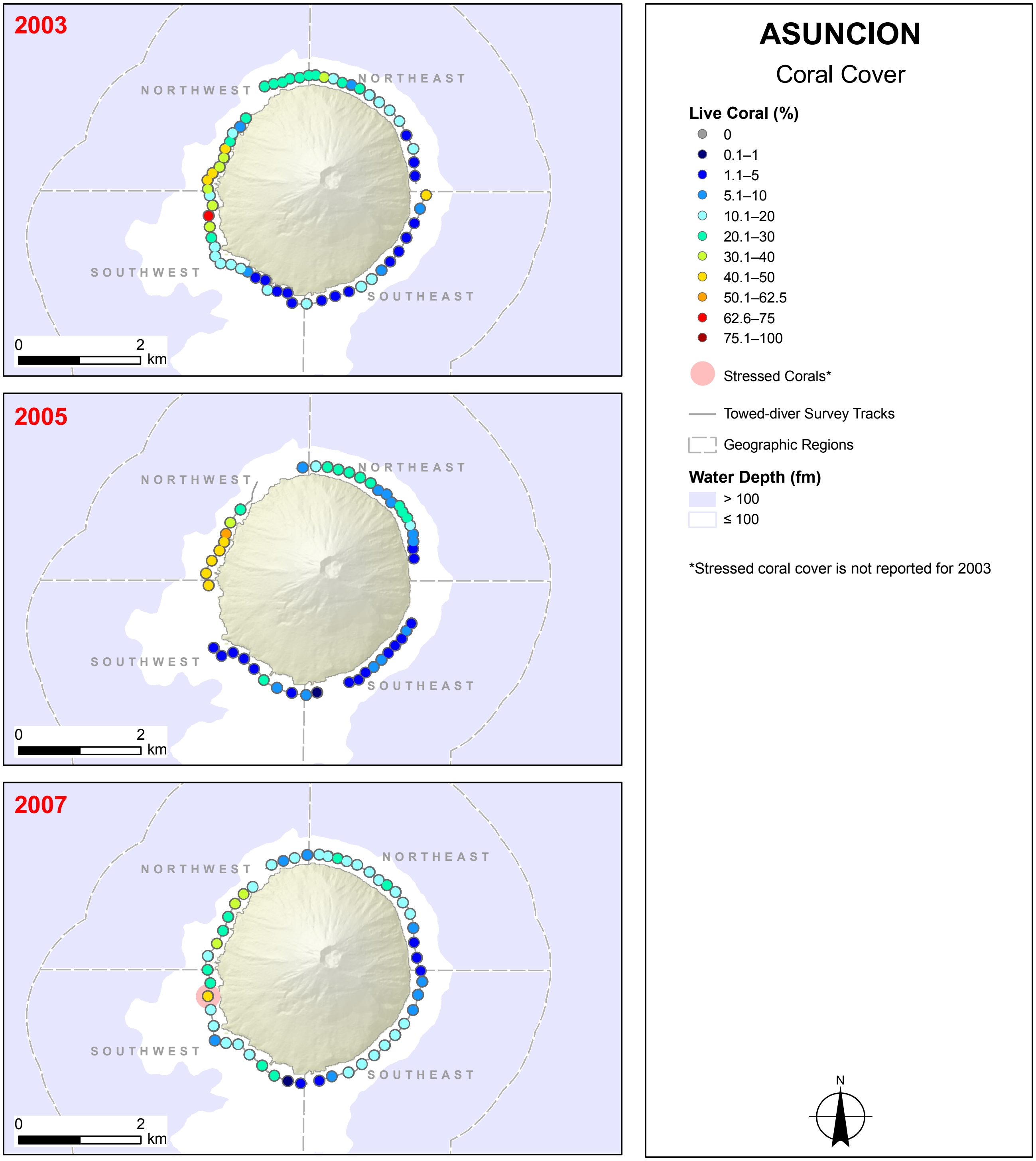


Figure 15.5.1a. Cover (%) observations of live and stressed hard corals from towed-diver benthic surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007. Each colored point represents an estimate of live coral cover over a 5-min observation segment with a survey swath of ~ 200 × 10 m (~ 2000 m^2). Pink symbols represent segments where estimates of stressed-coral cover were > 10%. Stressed-coral cover was measured as a percentage of overall coral cover in 2005 and 2007.

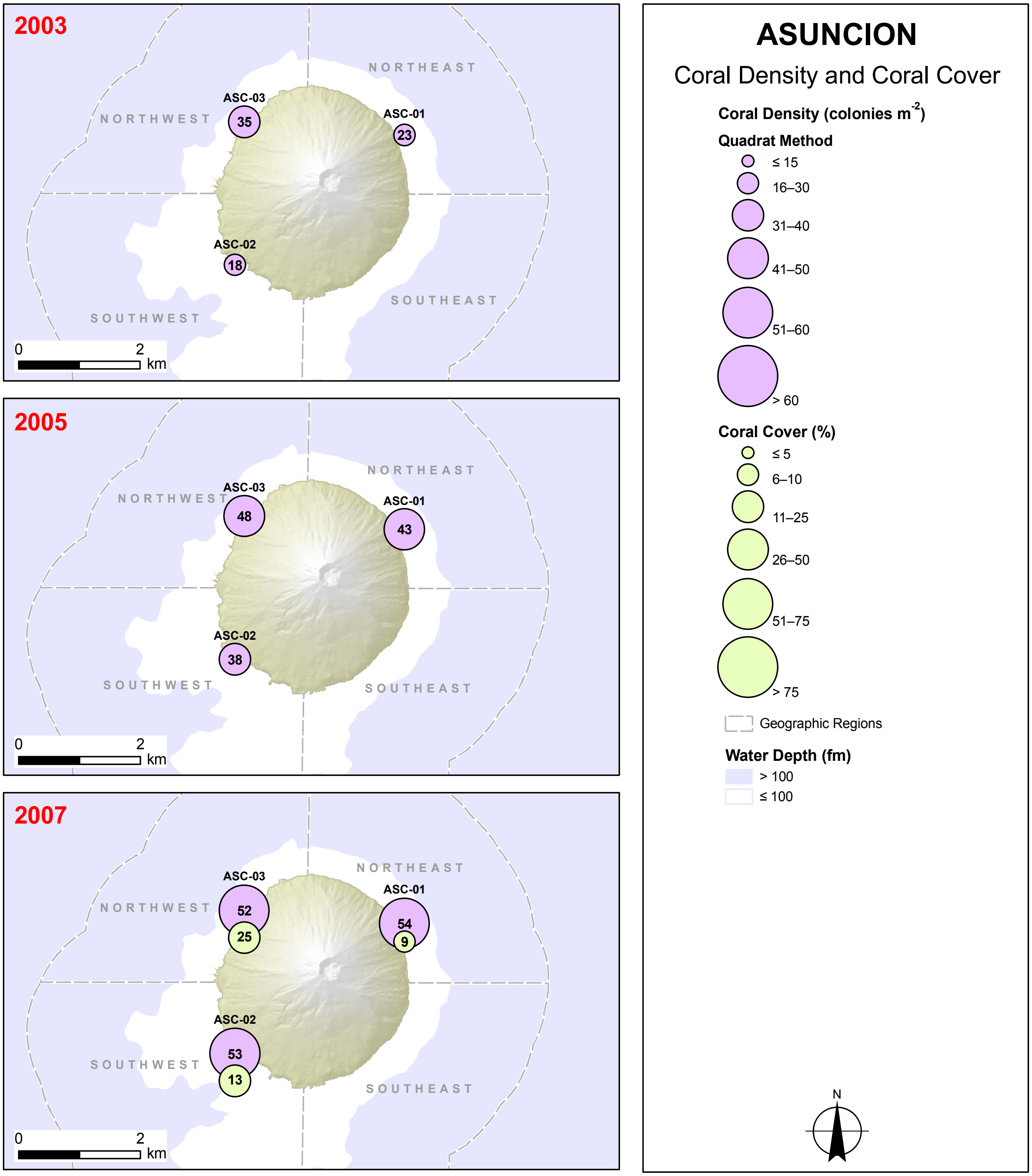


Figure 15.5.1b. Colony-density (colonies m^{-2}) observations of live hard corals from REA benthic surveys of forereef habitats conducted at Asuncion during MARAMP 2003, 2005, and 2007 as well as cover (%) observations of live corals from REA benthic surveys during MARAMP 2007. Values are provided within each symbol. The quadrat method was used to assess coral colony-densities.

Islandwide mean cover of live corals, estimated from towed-diver surveys of forereef habitats, essentially was the same in 2003, 2005, and 2007 (Fig. 15.5.1c): 18% (SE 1.9), 16% (SE 2.3), and 16% (SE 1.3). Congruent with these results from broad-scale towed-diver surveys, the overall sample mean from REA surveys conducted in 2007 was 15.7% (SE 5).

The quadrat method was used during the 3 MARAMP survey years to assess coral-colony density on forereef habitats at Asuncion. The overall sample mean of coral-colony density increased from 25.6 colonies m^{-2} (SE 5) in 2003 to 42.9 colonies m^{-2} (SE 3.0) in 2005 and 53 colonies m^{-2} (SE 0.5) in 2007. This observed increase in colony density between survey years may result from increased recruitment, fragmentation of existing colonies, or quadrat placement (Fig.15.5.1d).

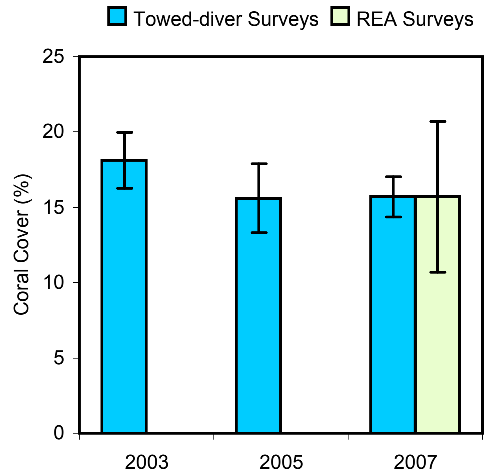


Figure 15.5.1c. Temporal comparison of mean live-coral-cover (%) values from REA and towed-diver benthic surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. No REA surveys using the line-point-intercept method were conducted at Asuncion in 2003 and 2005. Error bars indicate standard error (± 1 SE) of the mean.

Coral Generic Richness and Relative Abundance

Three REA benthic surveys of forereef habitats were conducted using the quadrat method at Asuncion during MARAMP 2003. At least 23 coral genera were observed at Asuncion. Generic richness ranged from 10 to 20 with a mean of 15.3 coral genera per site (SE 2.9). The highest generic diversity was recorded at ASC-03 in the northwest region, and the lowest generic diversity was found at ASC-01 in the northeast region (Fig. 15.5.1e, top panel).

Pavona was the most numerically abundant genus, accounting for 19.2% of the total number of colonies enumerated at Asuncion in 2003. All other genera individually accounted for < 10% of the total number of colonies. *Pocillopora* and *Porites* dominated the coral fauna at ASC-01, each accounting for 12.6% of the total number of colonies at that site. *Pavona* dominated the coral fauna at sites ASC-02 and ASC-03, accounting for 17.4% and 40.2% of the total number of colonies recorded at those sites.

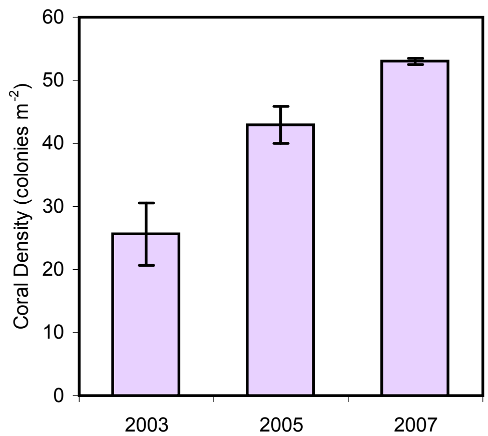


Figure 15.5.1d. Temporal comparison of mean coral-colony densities (colonies m^{-2}) from REA benthic surveys conducted on forereef habitats at Asuncion during MARAMP 2003, 2005, and 2007. The quadrat method was used in the 3 survey years to measure coral-colony density. Error bars indicate standard error (± 1 SE) of the mean.

Three REA benthic surveys of forereef habitats were conducted using the quadrat method at Asuncion during MARAMP 2005. At least 24 coral genera were observed at Asuncion. Generic richness ranged from 14 to 18 with a mean of 16.3 coral genera per site (SE 1.2). The highest generic diversity was recorded at ASC-03 in the northwest region, and the lowest generic diversity was found at ASC-01 in the northeast region (Fig. 15.5.1e, middle panel).

Pavona and *Pocillopora* were the most numerically abundant genera, accounting for 17.3% and 16.6% of the total number of colonies enumerated at Asuncion in 2005. All other genera individually accounted for < 10% of the total number of colonies. *Pavona*, *Pocillopora*, and *Porites* dominated at ASC-01, accounting for 22.7%, 21.5%, and 14% of the total number of colonies at that site. *Pocillopora* and *Pavona* dominated the coral fauna at ASC-02, accounting for 19.9% and 11.9% of the total number of colonies observed at that site. *Pavona* and *Favia* dominated at ASC-03, accounting for 17.2% and 10.4% of the total number of colonies found at that site.

Three REA benthic surveys of forereef habitats were conducted using the quadrat method at Asuncion during MARAMP 2007. At least 23 coral genera were observed at Asuncion. Generic richness ranged from 16 to 22 with a mean of 18.3 genera per site (SE 1.9). The highest generic diversity was recorded at ASC-03 in the northwest region, and the lowest generic diversity was found at ASC-01 in the northeast region (Fig. 15.5.1e, bottom panel).

Pocillopora and *Pavona* were the most numerically abundant genera, accounting for 18.5% and 13.1% of the total number of colonies enumerated at Asuncion in 2007. All other genera individually accounted for < 10% of the total number of colonies. *Pocillopora* and *Porites* dominated the coral fauna at ASC-01, accounting for 21.9% and 12.6% of the total number of colonies observed at that site. *Pocillopora* dominated at ASC-02, accounting for 26.8% of the total number of colonies recorded at that site. *Favia* and *Pavona* dominated at ASC-03, accounting for 17.8% and 21.2% of the total number of colonies found at that site.

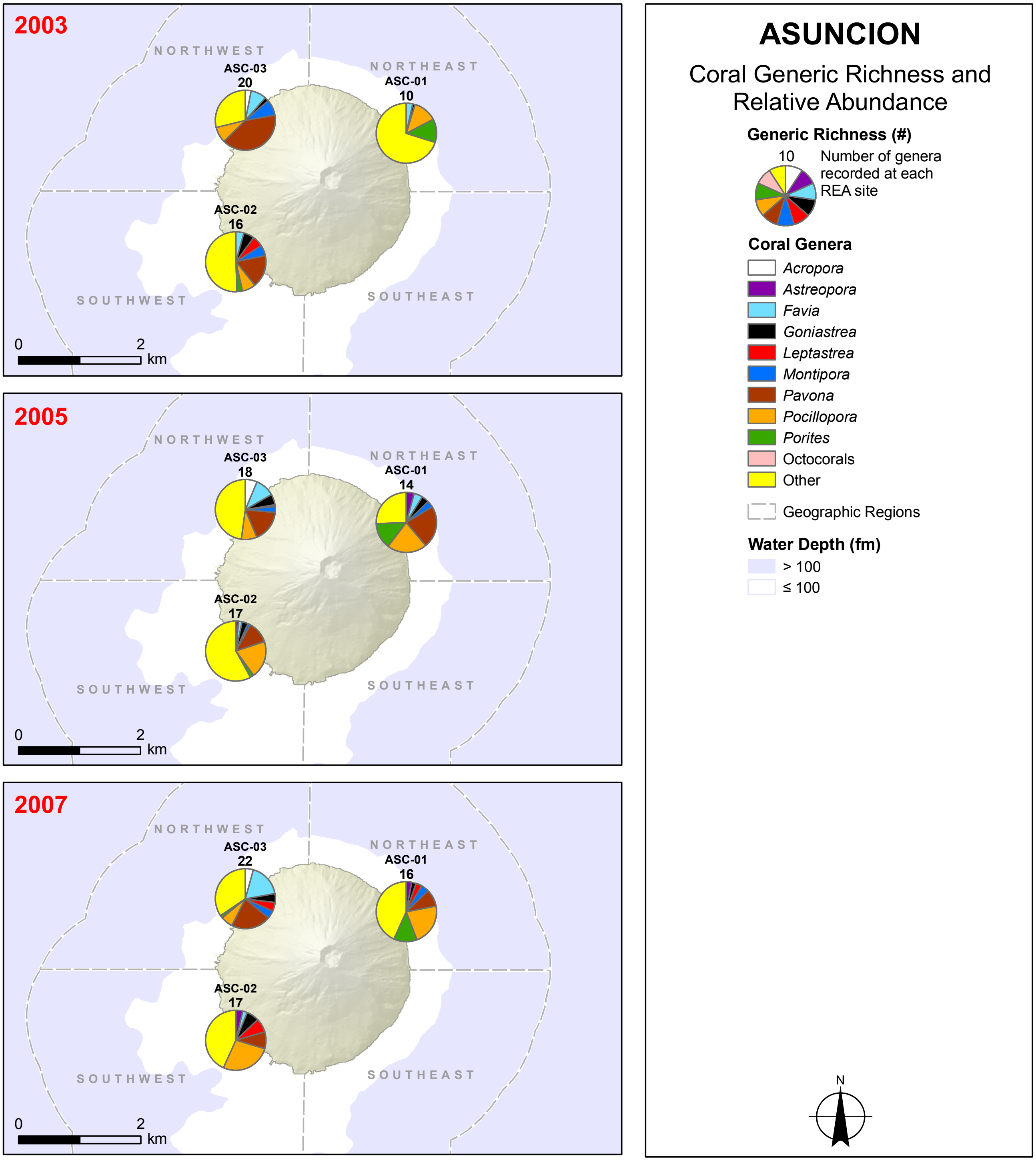


Figure 15.5.1e. Observations of coral generic richness and relative abundance of coral genera from REA benthic surveys of forereef habitats conducted at Asuncion during MARAMP 2003, 2005, and 2007. The pie charts indicate percentages of relative abundance of key coral genera. The quadrat method was used to survey coral genera.

The quadrat method was used in each of the 3 MARAMP survey years to assess generic richness on forereef habitats at Asuncion. The overall sample means were essentially the same in 2003, 2005, and 2007: 15.3 genera per site (SE 2.9) in 2003, 16.3 (SE 1.2) in 2005, and 18.3 (SE 1.9) in 2007 (Fig. 15.5.1f). The small variation between survey years likely results from variability in quadrat placement at individual sites.

Across the 3 MARAMP survey years, 29 coral genera were observed on forereef habitats at Asuncion. *Pavona* was an important component of the coral fauna, accounting for > 10% of the total number of colonies enumerated in the 3 survey years. *Pavona* was the most abundant genus in 2003 and 2005 and was the second-most abundant genus in 2007 surveys, accounting for 28.8%, 17.3%, and 13.1% of the total number of colonies enumerated. *Pocillopora* was the most abundant genus in 2007 surveys and the second-most abundant genus in 2005 surveys, accounting for 18.5% and 16.6% of the total number of colonies enumerated. All other genera accounted for < 10% of the total number of colonies recorded in the 3 survey years.

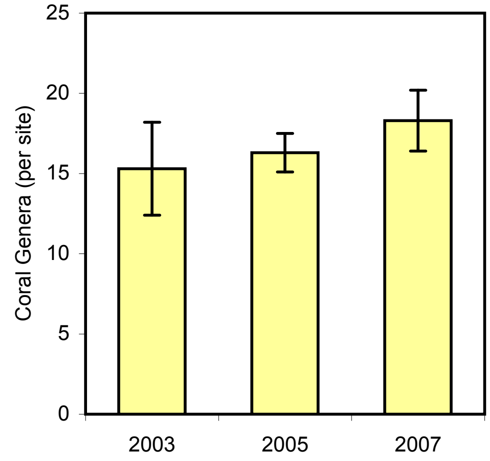


Figure 15.5.1f. Temporal comparison of overall mean numbers of coral genera per site from REA benthic surveys conducted on forereef habitats at Asuncion during MARAMP 2003, 2005, and 2007. The quadrat method was used to survey coral genera. Error bars indicate standard error (± 1 SE) of the mean.

Coral Size-class Distribution

During MARAMP 2003, 3 REA benthic surveys of forereef habitats were conducted at Asuncion using the quadrat method. The coral size-class distribution from these surveys shows that the majority (64.3%) of corals had maximum diameters ≤ 5 cm (Fig. 15.5.1g, top panel). The next 4 size classes (6–10, 11–20, 21–40, and 41–80 cm) accounted for 26.1%, 5.9%, 3.2%, and 0.5% of colonies recorded. No colonies with maximum diameters > 80 cm were observed. At all REA sites, a majority (> 53%) of corals were in the smallest size class (≤ 5 cm).

During MARAMP 2005, 3 REA benthic surveys of forereef habitats were conducted at Asuncion using the quadrat method. The coral size-class distribution from these surveys shows that the majority (70.2%) of corals had maximum diameters ≤ 5 cm (Fig. 15.5.1g, middle panel). The next 4 size classes (6–10, 11–20, 21–40, and 41–80 cm) accounted for 19%, 8%, 2.6%, and 0.2% of colonies recorded. No colonies with maximum diameters > 80 cm were observed. At all REA sites, a majority (> 54%) of corals were in the smallest size class (≤ 5 cm).

During MARAMP 2007, 3 REA benthic surveys of forereef habitats were conducted at Asuncion using the quadrat method. The coral size-class distribution from these surveys shows that the majority (77.6%) of corals had maximum diameters ≤ 5 cm (Fig. 15.5.1g, bottom panel). The next 4 size classes (6–10, 11–20, 21–40, and 41–80 cm) accounted for 16.7%, 3.5%, 1.6%, and 0.64% of colonies recorded. No colonies with maximum diameters > 80 cm were observed. At all REA sites, a majority (> 71%) of corals were in the smallest size class (≤ 5 cm).

The quadrat method was used to establish size-class distributions on forereef habitats at Asuncion during the 3 MARAMP survey years. Corals whose center fell within the borders of a quadrat (50 × 50 cm) were tallied and measured in 2 planar dimensions to the nearest centimeter. Fewer large colonies than small colonies can fall within a quadrat. This bias can contribute to higher counts of colonies in the smallest size classes and lower counts of colonies in the largest size classes compared to the actual relative colony densities. At each site, 15 or 16 such quadrats were examined (total survey area = 3.75 or 4 m^2), enabling observers to closely inspect and record each coral colony within the quadrat. For more on these survey methods see Chapter 2, “Methods and Operational Background, Section 2.4.5: “Corals and Coral Disease.”

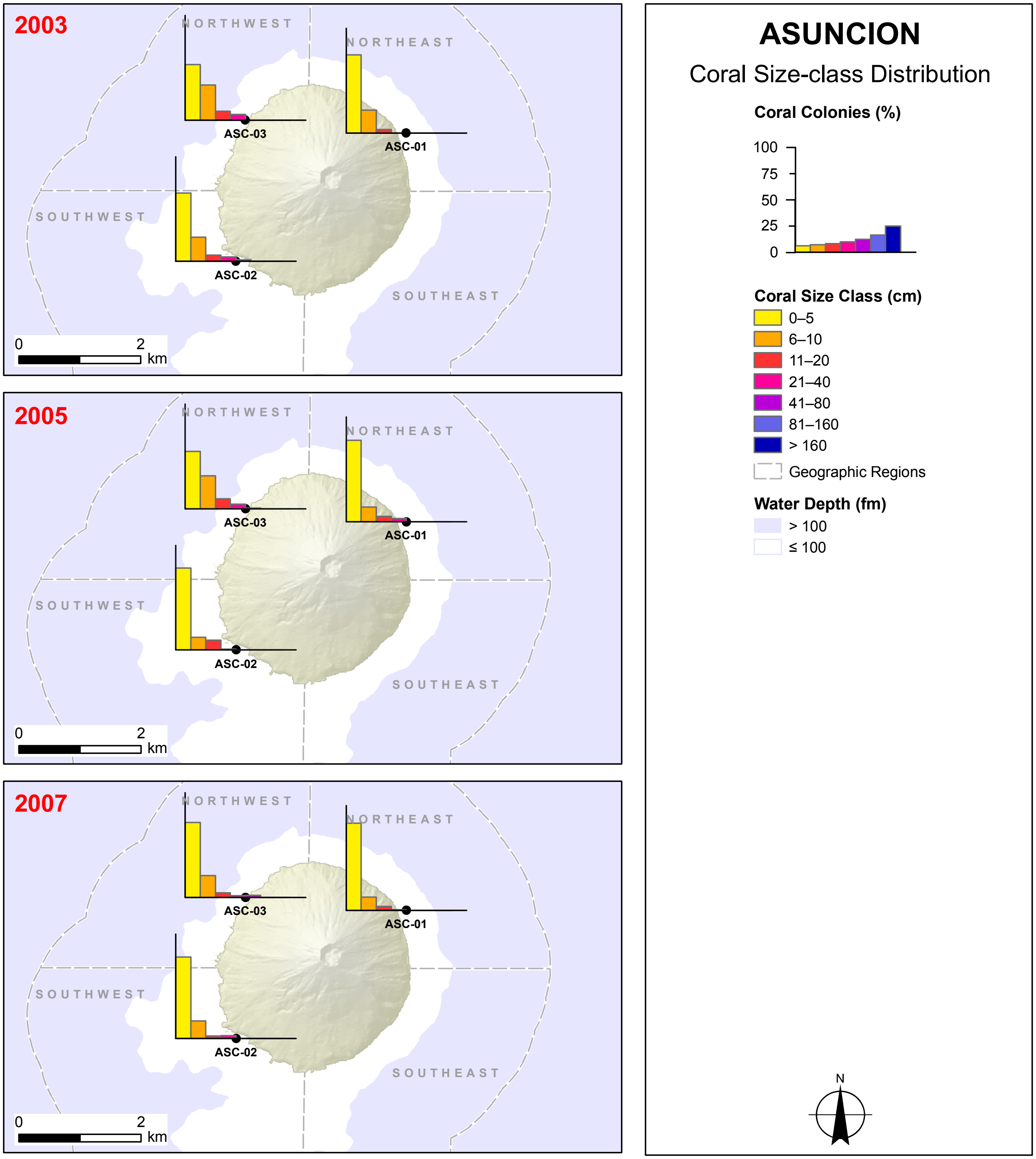


Figure 15.5.1g. Size-class distributions of hard corals from REA benthic surveys of forereef habitats conducted at Asuncion during MARAMP 2003, 2005, and 2007. The observed size classes are color coded in a size-frequency chart at each REA site. The quadrat method was used to size corals.

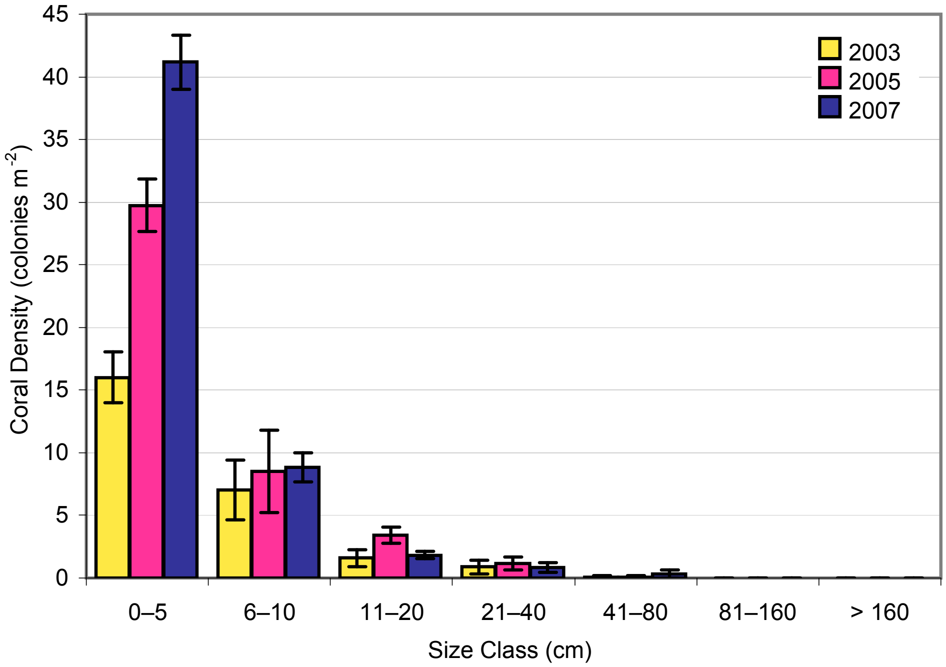


Figure 15.5.1h. Mean coral-colony densities (colonies m^{-2}) by size class from REA benthic surveys of forereef habitats conducted at Asuncion during MARAMP 2003, 2005, and 2007. The quadrat method was used in the 3 survey years to size corals. Error bars indicate standard error (± 1 SE) of the mean.

In each of the 3 MARAMP survey years, the number of coral colonies in the smallest size class (0–5 cm) was > 15 colonies m^{-2} (Fig. 15.5.1h). The overall mean proportion of colonies in the smallest size class increased from 64.3% in 2003 to 70.2% in 2005 to 77.6% in 2007. Increase in frequency of the smallest size class may result from recruitment, fragmentation of existing colonies, or both. The relative proportion of corals in the other size classes showed some variability among survey years as well.

15.5.2 Surveys for Coral Disease and Predation

During MARAMP 2007, REA benthic surveys for coral disease and predation were conducted at 3 sites on forereef habitats at Asuncion, covering a total area of 900 m^2. Surveys detected 10 cases of disease, translating to an overall mean prevalence of 0.02% (SE 0.01), excluding predation. Coral-colony counts at all REA sites at Asuncion were conducted using the quadrat method, resulting in high coral-colony densities and, therefore, low disease prevalence values, relative to the levels found at sites at other islands surveyed using the belt-transect method.

Two major disease conditions were detected on forereefs at Asuncion: fungal infection and skeletal growth anomalies. Of the 3 sites surveyed, 2 contained disease: ASC-01 and ASC-03 (Fig. 15.5.2a; the values of overall prevalence shown in Figure 15.5.2a include predation). ASC-01 in the northeast region contained 80% of recorded cases, all of which corresponded to fungal infection (Fig. 15.5.2b). This condition affected a variety of coral genera, including *Cyphastrea*, *Favia*, *Psammocora*, *Hydnophora*, and *Pavona*. The other 20% of recorded lesions were detected at ASC-03 in the northwest region and involved skeletal growth anomalies, all on corals of the genus *Porites*.

Cases of coral predation attributable to COTS or corallivorous snails, such as snails from the genus *Drupella*, were also observed at Asuncion but only at ASC-03.

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Figure 15.5.2a. Overall prevalence (%) observations of coral diseases and predation from REA benthic surveys of forereef habitats conducted at Asuncion during MARAMP 2007. Prevalence was computed based on the estimated total number of coral colonies within the area surveyed for disease at each REA site. The color-coded portions of the pie charts indicate disease-specific prevalence.

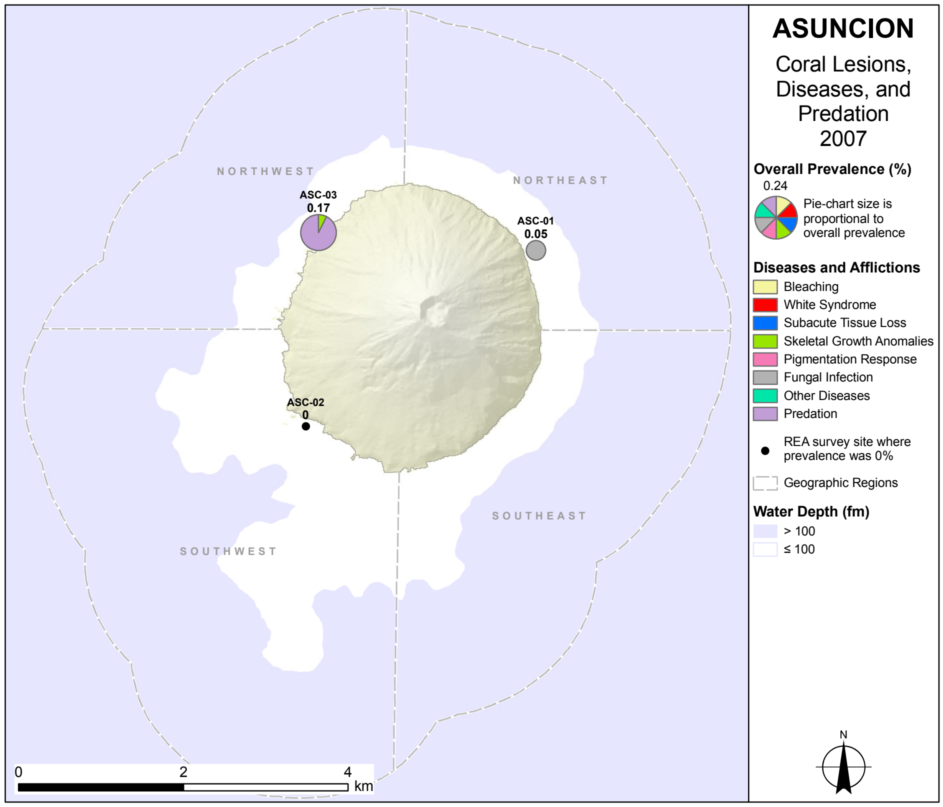
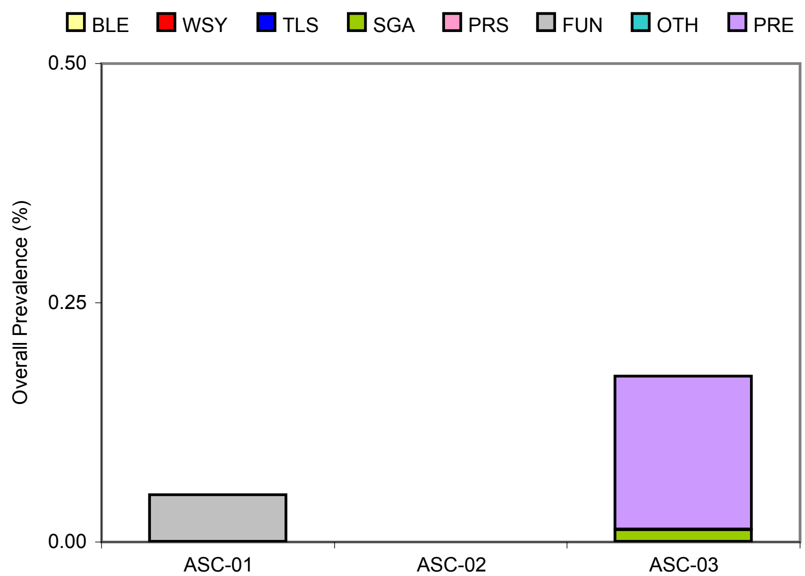


Figure 15.5.2b. Overall prevalence (%) observations of coral diseases and predation from REA benthic surveys of forereef habitats conducted at Asuncion during MARAMP 2007. Prevalence was computed based on the estimated total number of coral colonies within the area surveyed for disease at each REA site. The order of conditions presented in the bars is the same as the order in the legend. BLE: bleaching; WSY: white syndrome; TLS: subacute tissue loss; SGA: skeletal growth anomalies; PRS: pigmentation response; FUN: fungal infection; OTH: algal and cyanophyte infections and other lesion of unknown etiology; PRE: predation by COTS or corallivorous snails.



15.6 Algae and Algal Disease

15.6.1 Algal Surveys

Algal Cover: Macroalgae and Turf Algae

From MARAMP 2003 towed-diver surveys, mean macroalgal cover on forereef habitats around the island of Asuncion was 51% (SE 2). Observations of macroalgal cover in 2003 included both macroalgae and turf algae. The survey with the highest mean macroalgal cover of 63%, within a range of 10.1%–75%, occurred in the southwest region (Fig. 15.6.1a, top left panel). The habitat in this area was characterized as pavement reef of medium-high complexity. The majority of the remaining surveys reported rock boulder habitat where macroalgae also appeared to thrive. The surveys in the southwest and northeast regions each reported greater than average macroalgal cover for Asuncion with means of 55% and 53%. Estimates of macroalgal cover never were < 40% in 2003 at Asuncion.

Five TOAD surveys completed at Asuncion during MARAMP 2003 were conducted at depths of 20–120 m. Analyses of TOAD video footage obtained from 3 surveys suggested very low macroalgal cover, with only the occasional video frame (8% of analyzed frames) from the southernmost survey, at depths of 111–119 m, showing cover of 20%.

From MARAMP 2005 towed-diver surveys, mean cover of macroalgae on forereef habitats around Asuncion was 5% (SE 1.3). The survey with the highest mean macroalgal cover of 14%, within a range of 5.1%–50%, occurred primarily in the southwest region (Fig. 15.6.1a, middle left panel), where habitat complexity was medium-low to medium. All other surveys reported less than average macroalgal cover for Asuncion, never exceeding 4%.

From MARAMP 2007 towed-diver surveys, mean cover of macroalgae around Asuncion was 19% (SE 2.1). The survey with the highest mean macroalgal cover of 43%, within a range of 30.1%–62.5%, occurred along the border between the northeast and northwest regions (Fig. 15.6.1a. bottom left panel). Steep rock reef of medium-high complexity, largely dominated by species of the brown alga *Padina*, was the main structural habitat observed during this survey. Remaining surveys reported cover values lower than the overall mean for Asuncion. The lowest macroalgal cover was observed during a 10-segment survey in the southeast region with a mean of 4%. Species of the green algal genera *Caulerpa* and *Halimeda* accounted for the majority of macroalgal-cover observations around Asuncion (except for the survey along the border of the northeast and northwest regions).

During MARAMP 2007, 3 REA benthic surveys of forereef habitats around Asuncion were conducted using the line-point-intercept method. Site-specific estimates of macroalgal cover ranged from 0% to 2% with an overall sample mean of 1% (SE 0.6). No macroalgae were observed in the northeast region at REA site ASC-01 (Fig. 15.6.1b). At both ASC-02 in the southwest region and at ASC-03 in the northwest region, macroalgal cover was 2%.

Turf-algal cover from these REA benthic surveys in 2007 ranged from 25.5% to 85.3% with an overall sample mean of 59% (SE 17.6). The highest turf-algal cover was observed in the northeast region at ASC-01 (Fig. 15.6.1b). Turf-algal cover was also high (65.7%) in the northwest region at ASC-03.

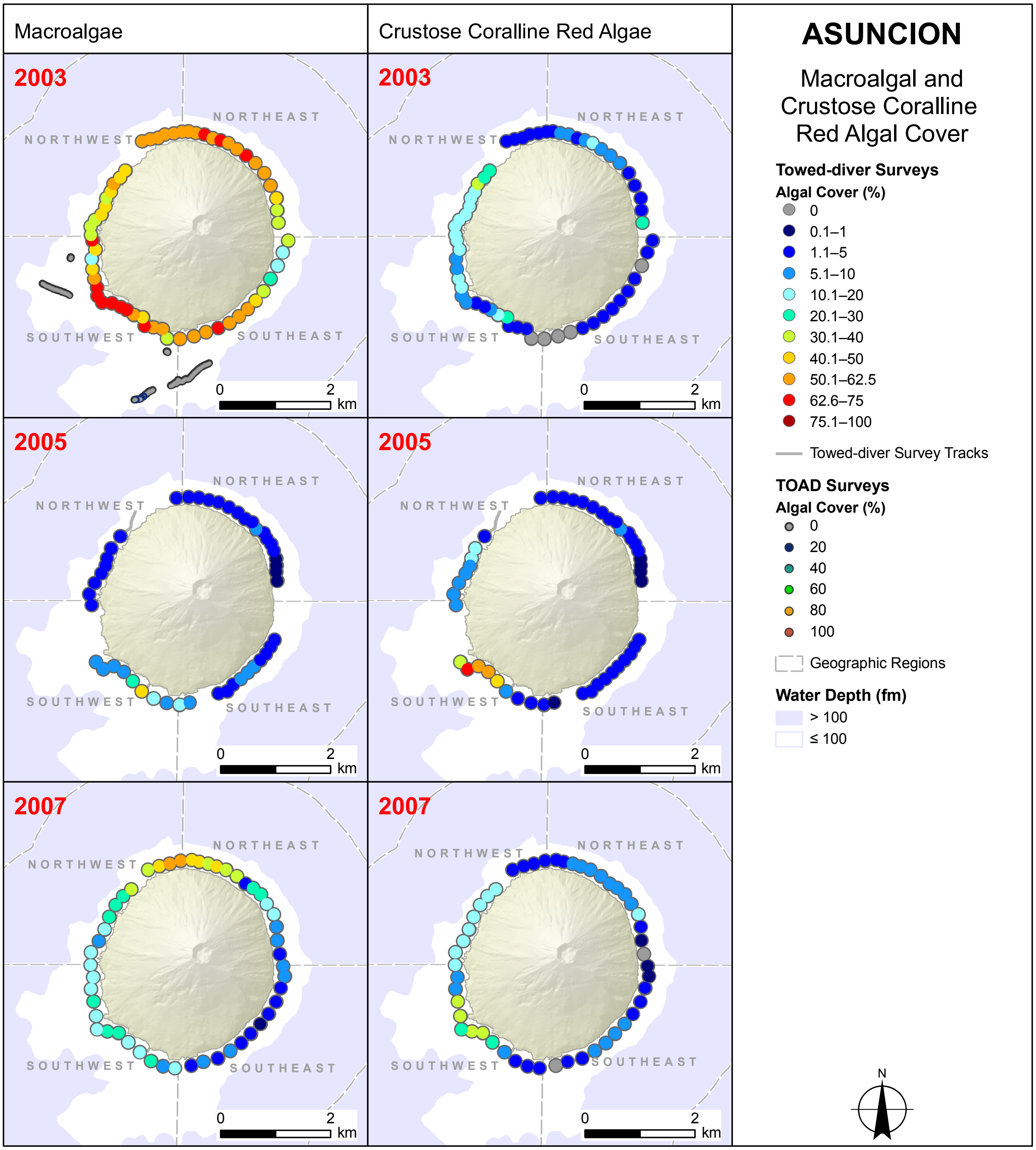


Figure 15.6.1a. Cover (%) observations for macroalgae and crustose coralline red algae from towed-diver benthic surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007. Each large, colored point represents an estimate over a 5-min observation segment with a survey swath of ~ 200 × 10 m (~ 2000 m²). The 2003 macroalgal panel shows observations of both macroalgae and turf algae (towed-diver surveys included turf algae only during MARAMP 2003). In this panel, each small, colored point represents an estimate of algal cover from TOAD surveys.

Algal Cover: Crustose Coralline Red Algae

From MARAMP 2003 towed-diver surveys, mean cover of crustose coralline red algae on forereef habitats around Asuncion was 8% (SE 1). Two surveys with the highest crustose-coralline-red-algal cover, each recording a mean of 19%, within a range of 10.1%–40%, occurred in the northwest region and in the southwest region (Fig. 15.6.1a, top right panel). Rock boulders and continuous reef of medium-high to high complexity were the dominant structural features in both surveys.

An additional survey in the southwest region was the only other survey to report greater than average crustose-coralline-red-algal cover for Asuncion, with a mean of 9%. In comparison to these 3 surveys, all other surveys reported low values of crustose-coralline-red-algal cover for Asuncion with means ranging from 2.5% to 7.1%.

From MARAMP 2005 towed-diver surveys, mean cover of crustose coralline red algae on forereef habitats around Asuncion was 9% (SE 2.8). The survey with the highest mean crustose-coralline-red-algal cover of 23%, within a range of 1.1%–75%, occurred in the southwest region (Fig. 15.6.1a, middle right panel). The low segment values from this survey corresponded to flat, sandy terrain, and the remainder of this surveyed area hosted crustose-coralline-red-algal cover of 30.1%–75%. In contrast, all other surveys around Asuncion reported less than average crustose-coralline-red-algal cover for this island, with means ranging from 1.8% to 7.1% in the southeast and northwest regions.

From MARAMP 2007 towed-diver surveys, mean cover of crustose coralline red algae on forereef habitats around Asuncion was 10% (SE 1.4). The survey with the highest crustose-coralline-red-algal cover of 18%, within a range of 1.1%–40%, occurred in the southwest region (Fig. 15.6.1a, bottom right panel). The adjacent survey in the northwest region reported mean cover of 13.5%. All other surveys reported less than average values of cover for Asuncion, with means ranging from 3.5% to 4.8%.

During MARAMP 2007, 3 REA benthic surveys were conducted using the line-point-intercept method at Asuncion. Site-specific estimates of crustose-coralline-red-algal cover ranged from 0% to 39.2% with an overall sample mean of 13% (SE 1.5). Crustose-coralline-red-algal cover was observed only at ASC-02 in the southwest region (Fig. 15.6.1b).

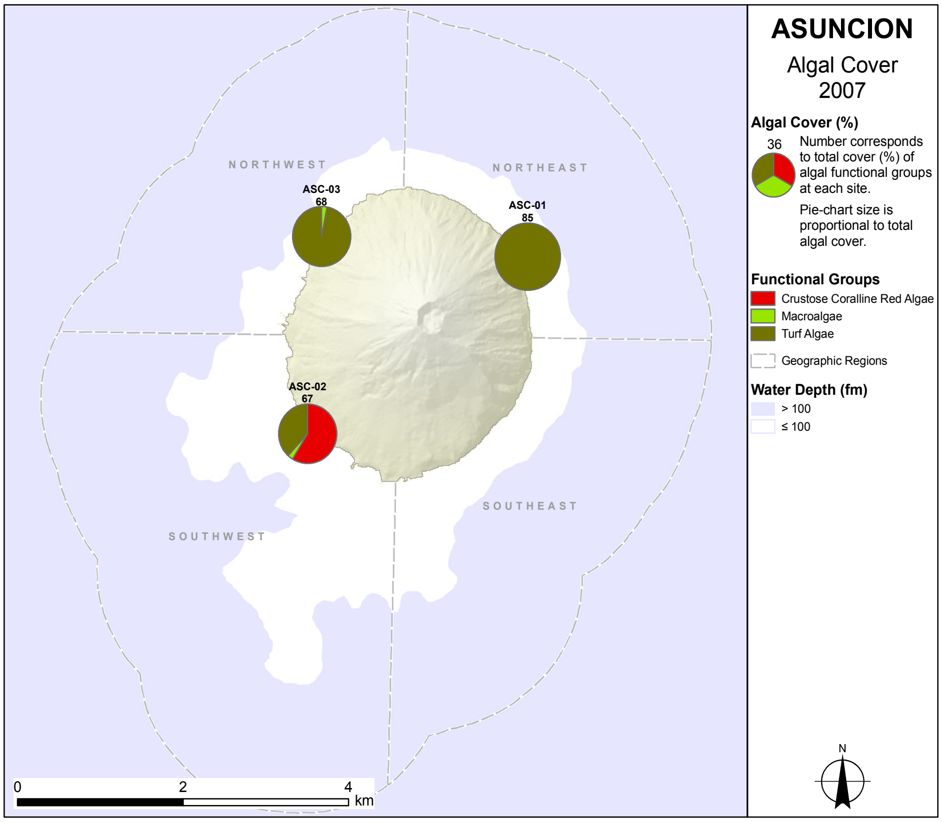


Figure 15.6.1b. Observations of algal cover (%) from REA benthic surveys of forereef habitats conducted using the line-point-intercept method at Asuncion during MARAMP 2007. The pie charts indicate algal cover by functional group, and values of total algal cover are provided above each symbol.

Algal Cover: Temporal Comparison

Between MARAMP survey years, islandwide mean cover of macroalgal populations around Asuncion, based on towed-diver surveys on forereef habitats, varied as much as 46% (Fig. 15.6.1c). Reefs in the northeast and southwest regions generally hosted higher benthic cover of macroalgae than did the other 2 regions. When considering survey results, keep in mind that turf algae were included, along with macroalgae, in towed-diver surveys of macroalgal cover only in 2003. Other factors, such as a change in season between survey periods, could have contributed to differences in algal cover (for information about data limitations, see Chapter 2: "Methods and Operational Background," Section 2.4: "Reef Surveys").

Crustose-coralline-red-algal populations around Asuncion, based on towed-diver surveys on forereef habitats, were similar in islandwide average cover of the benthos between MARAMP survey years (Fig. 15.6.1c). Cover of crustose coralline red algae increased by 4% in the southwest region between MARAMP 2003 and 2005 and by 6% in the northwest region between MARAMP 2005 and 2007. Cover in the southwest region decreased by ~ 5% between 2005 and 2007, but this region still hosted the highest cover of crustose coralline red algae recorded in 2007.

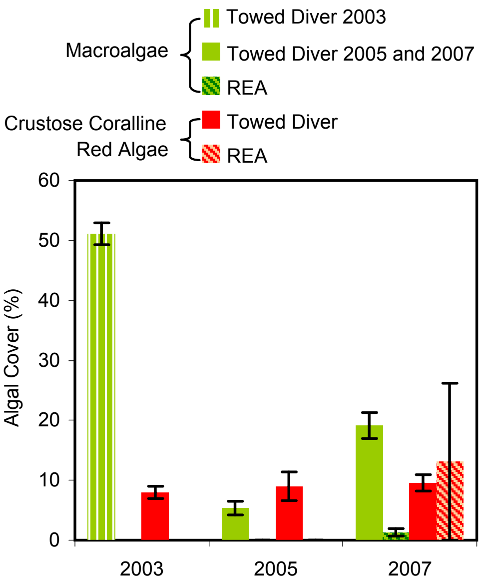


Figure 15.6.1c. Temporal comparison of algal-cover (%) values from surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. Values of macroalgal cover from towed-diver surveys include turf algae only in 2003. No REA surveys using the line-point-intercept method were conducted in 2003 and 2005. Error bars indicate standard error (± 1 SE) of the mean.

Macroalgal Genera and Functional Groups

In the field, because of their small size or similarity in appearance, turf algae, crustose coralline red algae, cyanophytes (blue-green algae), and branched, nongeniculate coralline red algae were lumped into functional group categories. The generic names of macroalgae from field observations are tentative, since microscopic analysis is necessary for proper taxonomic identification. The lengthy process of laboratory-based taxonomic identification of all algal species collected at REA sites is about 90% complete for the northern islands with hundreds of species identified so far. Ultimately, based on this microscopic analysis, the generic names of macroalgae reported in this section may change and algal diversity reported for each REA site likely will increase.

During MARAMP 2003, REA benthic surveys were conducted at 3 sites on forereef habitats at Asuncion. In the field, 10 macroalgal genera (1 red, 3 brown, and 6 green), containing at least 11 species, as well as 3 additional algal functional groups—turf algae, crustose coralline red algae, and cyanophytes—were observed. ASC-03 in the northwest region had the highest macroalgal generic diversity with 7 genera, containing 8 species, documented in the field. The lowest macroalgal generic diversity was found in the southwest region at ASC-02 with 4 species representing 4 genera recorded.

The brown algal species *Lobophora variegata* was ubiquitous at every site surveyed at Asuncion in 2003, occurring in 75% of all sampled photoquadrats (Fig. 15.6.1d, top panel). The green algal genus *Neomeris* also was common, although its occurrence was higher at ASC-02 in the southwest region with 33.3% than at the sites on the northern coast, ASC-01 and ASC-03, where occurrence was 8.3% at each site. Of the remaining 8 taxa tentatively identified, most were observed only at 1 or 2 sites, making distinctive spatial patterns of distribution difficult to determine.

Turf algae were exceptionally common in 2003, occurring in 97% of photoquadrats sampled at Asuncion. Turf-algal communities were common at all sites. Crustose coralline red algae also were observed at all sites, occurring in 22% of sampled photoquadrats. Cyanobacteria, found in 0–50% of sampled photoquadrats, were common only at ASC-02 in the southwest region (Fig. 15.6.1d, top panel).

During MARAMP 2005, REA benthic surveys were conducted at 3 sites on forereef habitats at Asuncion. In the field, 10 macroalgal genera (1 red, 3 brown, and 6 green), containing at least 10 species, as well as 4 additional algal functional groups—turf algae, crustose coralline red algae, nongeniculate calcified red algae, and cyanophytes—were observed. ASC-02 in the southwest region had the highest macroalgal generic diversity with 8 genera, containing 8 species, documented in the field. The lowest macroalgal genera diversity was found at ASC-01 in the northeast region with 5 species representing 5 genera recorded.

Lobophora variegata was exceptionally common at sites surveyed at Asuncion in 2005 (Fig. 15.6.1d, middle panel). Besides *Lopophora*, *Halimeda* and the calcified, red algal genus *Jania* were the only other algal genera recorded at all 3 sites surveyd at Asuncion, occurring in 27.7% and 19.4% of sampled photoquadrats. Although not present at every site, species of the green macroalgal genera *Chlorodesmis*, *Caulerpa*, and *Rhipidosiphon* were common at Asuncion, occurring in 30.5%, 22.2%, and 16.7% of sampled photoquadrats. Of the 10 taxa identified at Asuncion, 8 were found in the southwest region at ASC-02, and only 5 and 6 taxa were found at the 2 sites on the northern coast. Species of the green algal genera

Dictyosphaeria and *Rhipidosiphon* and the brown algal genus *Dictyota* were found exclusively at ASC-02; conversely, species of *Neomeris* were found, in low abundance, at only ASC-01 and ASC-03 on the northern coast.

Turf algae and crustose coralline red algae were exceptionally common, occurring in 97% and 78% of photoquadrats sampled at Asuncion in 2005 (Fig. 15.6.1d, middle panel). Cyanobacteria were recorded only at ASC-03 in the northwest region, occurring in 8.3% of the photoquadrats sampled at this site.

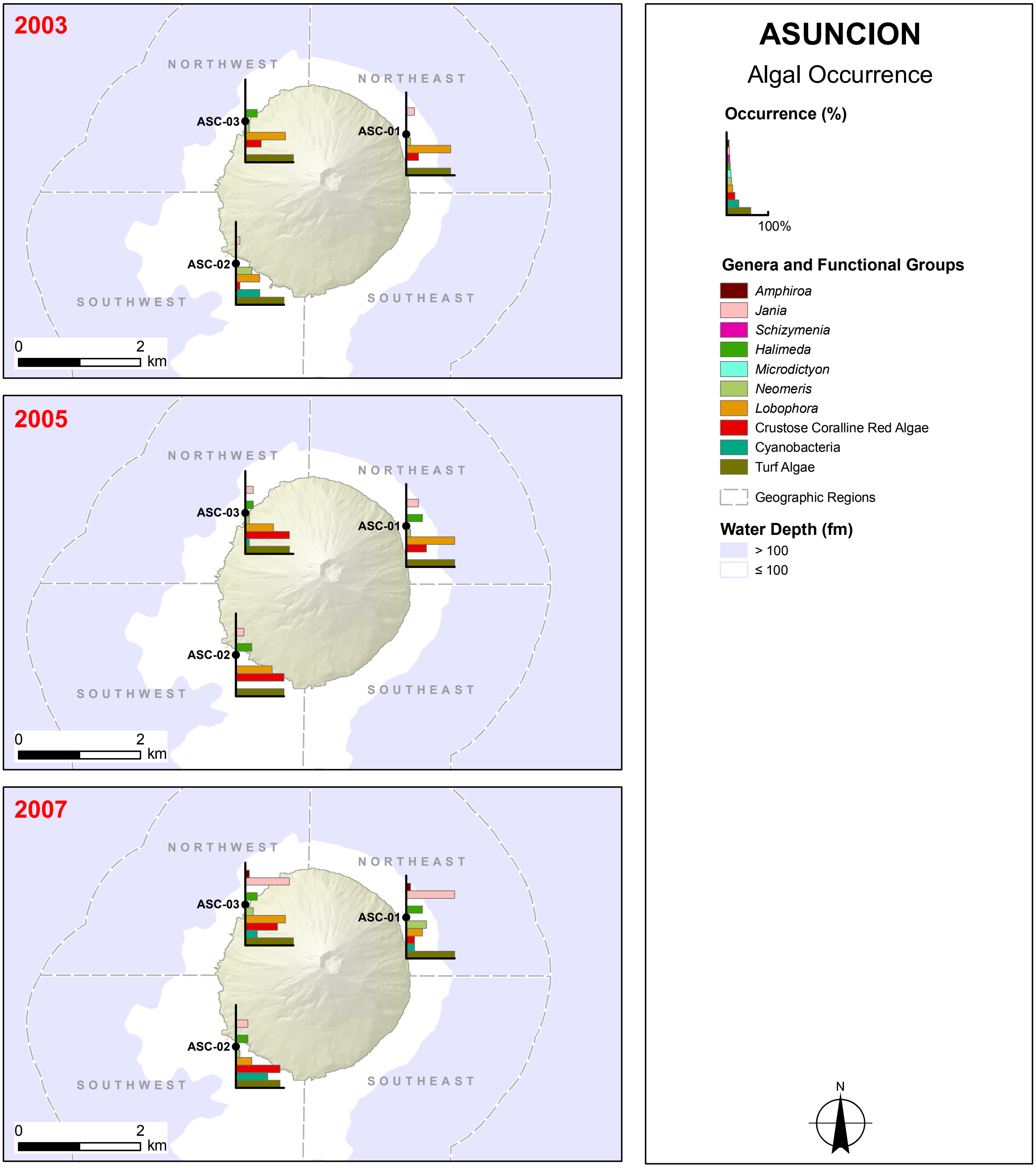


Figure 15.6.1d. Observations of occurrence (%) for select macroalgal genera and algal functional groups from REA benthic surveys of forereef habitats conducted at Asuncion during MARAMP 2003, 2005, and 2007. Occurrence is equivalent to the percentage of photoquadrats in which an algal genus or functional group was observed. The length of the x-axis denotes 100% occurrence.

During MARAMP 2007, REA benthic surveys were conducted at 3 sites on forereef habitats at Asuncion. In the field, 14 macroalgal genera (4 red, 7 green, and 3 brown), containing at least 14 species, as well as 3 additional algal functional groups—turf algae, crustose coralline red algae, and cyanophytes—were observed. ASC-02 in the southwest region had the highest macroalgal generic diversity with 12 genera, containing 12 species, documented in the field. At both ASC-01 and ASC-03, 8 species representing 8 genera were recorded.

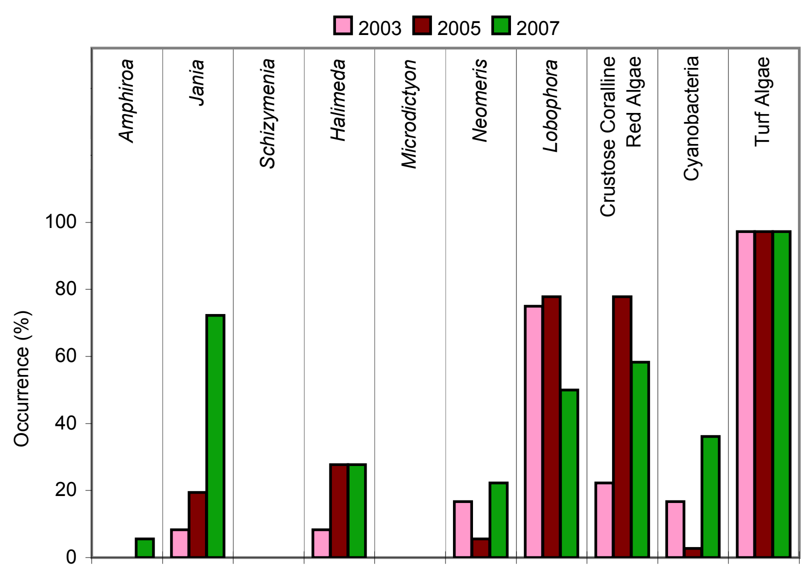
Species of the genera *Jania*, *Lobophora*, *Caulerpa*, and *Halimeda* were all ubiquitous at the 3 sites surveyed at Asuncion in 2007, occurring in 72%, 50%, 50%, and 27.8% of sampled photoquadrats (Fig. 15.6.1d, bottom panel). The occurrence of each taxon was quite variable between sites. Species of *Jania* occurred in only 25% of photoquadrats sampled at ASC-02; however, it was extremely abundant at the 2 sites on the northern coast, occurring in 91.7% and 100% of photoquadrats sampled at ASC-03 and ASC-01. *Lobophora variegata* was found in 33.3% of sampled photoquadrats at both ASC-01 and ASC-02 and in 83% of sampled photoquadrats at ASC-03. Species of *Halimeda* were present in 27.8% of photoquadrats sampled at Asuncion.

Turf algae, crustose coralline red algae, and cyanobacteria were all exceptionally common in 2007, occurring in 97%, 58%, and 36% of photoquadrats sampled at Asuncion. Turf algae was found in 91.7%–100% of sampled photoquadrats, and crustose coralline red algae and cyanobacteria, both with more variable occurrence values, were recorded in 16.7%–66.7% of sampled photoquadrats (Fig. 15.6.1d, bottom panel).

A marginal increase in macroalgal biodiversity from 10 to 14 genera between 2005 and 2007 was recorded at Asuncion. The genera discovered in 2007 that were not previously recorded in 2003 or 2005 were the green algal genus *Tydemania* and the red algal genera *Peyssonnelia*, *Amphiroa*, and *Hypnea*. In 2005, algae whose identifications were unknown to field observers were recorded in as many as 16.7% of photoquatrats sampled at ASC-01 in the northeast region and 41.6% at ASC-03 in the northwest region. Because the 4 new genera found in 2007 were known to phycologists working in the field, it is unlikely that they correspond to the unknown taxa recorded in 2005. Substantial increases were observed in abundance of species of *Jania*, which occurred in only 8% of photoquadrats sampled at Asuncion in 2003 but in 19% and 72% of sampled photoquadrats in 2005 and 2007 (Fig. 15.6.1e). The occurrence of species of *Halimeda* also increased. Species of *Halimeda* were recorded in only 8% of photoquadrats sampled at Asuncion in 2003 but were found in 27% of sampled photoquadrats in 2005 and 2007. *Lobophora variegata* was recorded in 75% and 77% of sampled photoquadrats in 2003 and 2005 and then only 50% in 2007. The genera *Neomeris* and *Caulerpa* also were common in the 3 MARAMP survey years. The green algal genera *Rhipidosiphon* and *Chlorodesmis* were common in 2005 but uncommon in 2007, whereas species of *Padina* and *Peysonnelia* were common in 2007 but not in 2005.

Occurrence of turf algae on forereef habitats at Asuncion remained consistent between the 3 MARAMP survey years, and this functional group was recorded in 97.2% of sampled photoquadrats during MARAMP 2003, 2005, and 2007 (Fig. 15.6.1e). The abundance of cyanobacteria appeared variable between survey years, decreasing in occurrence from 16.6% in 2003 to 2.7% in 2005 and then increasing to 36% in 2007. No other temporal trends of increasing or decreasing abundance of functional groups were obvious.

Figure 15.6.1e. Temporal comparison of occurrence (%) values from REA benthic surveys of algal genera and functional groups conducted on forereef habitats at Asuncion during MARAMP 2003, 2005, and 2007.



15.6.2 Surveys for Coralline-algal Disease

During MARAMP 2007, REA benthic surveys for coralline-algal disease were conducted in concert with coral-disease assessments at 3 sites on forereef habitats at Asuncion. These surveys covered a total reef area of 900 m^2 and detected only 1 case of coralline lethal orange disease at site ASC-02 (Fig. 15.6.2a).

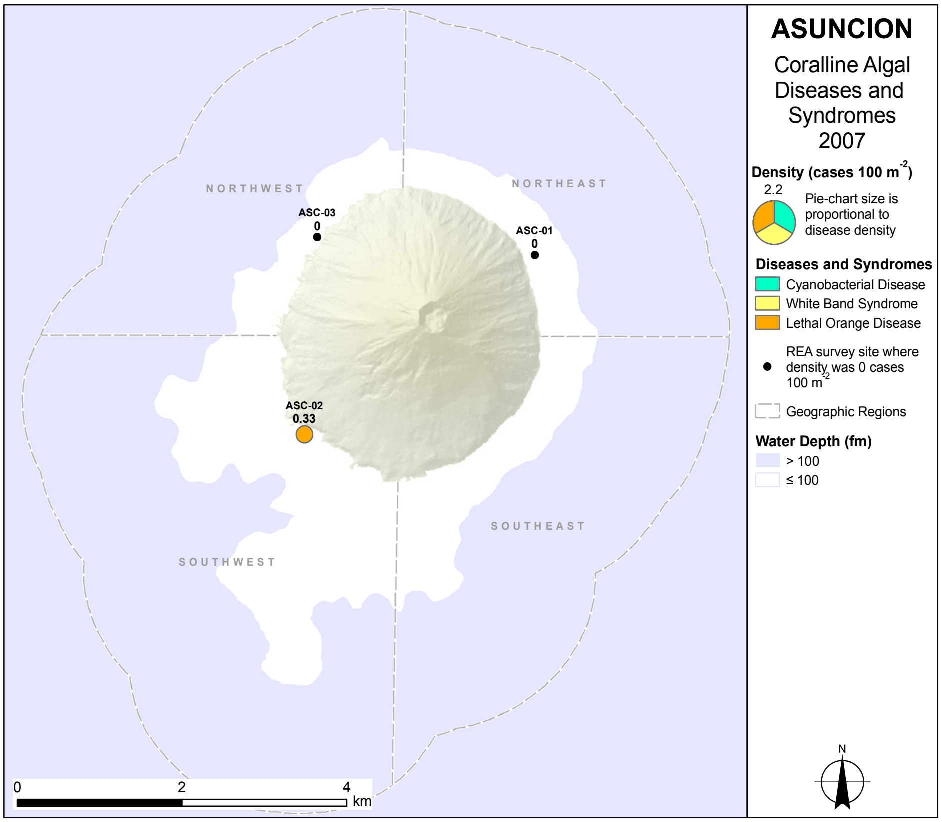


Figure 15.6.2a. Densities (cases 100 m^{-2}) of coralline-algal diseases from REA benthic surveys conducted on forereef habitats at Asuncion during MARAMP 2007.

15.7 Benthic Macroinvertebrates

15.7.1 Benthic Macroinvertebrates Surveys

Four groups of benthic macroinvertebrates—sea urchins, sea cucumbers, giant clams, and crown-of-thorns seastars (COTS)—were monitored on forereef habitats around the island of Asuncion through REA and towed-diver benthic surveys during MARAMP 2003, 2005, and 2007. This section describes by group the results of these surveys. A list of additional taxa observed during the REA invertebrate surveys is provided in Chapter 3: "Archipelagic Comparisons."

Monitoring these 4 groups of ecologically and economically important taxa provides insight into the population distribution, community structure, and habitats of the coral reef ecosystems of the Mariana Archipelago. High densities of the corallivorous COTS can affect greatly the community structure of reef ecosystems. Giant clams are filter feeders that are sought after in the Indo-Pacific for their meat, which is considered a delicacy, and for their shells. Sea cucumbers, sand-producing detritus foragers, are harvested for food. Sea urchins are important algal grazers and bioeroders.

In 2003, 3 REA benthic surveys and 6 towed-diver surveys were conducted around Asuncion. In 2005, 3 REA surveys and 5 towed-diver surveys were performed, and in 2007, 2 REA surveys and 5 towed-diver surveys were conducted. When considering results from towed-diver surveys, keep in mind that cryptic or small organisms can be difficult for divers to see, so the density values presented in this report, especially of giant clams and sea urchins, may under-represent the number of individuals present.

Overall, both REA and towed-diver surveys suggested low daytime macroinvertebrate abundance on forereef habitats around Asuncion compared to the rest of the Mariana Archipelago. Minor fluctuations in observed densities between MARAMP survey periods occurred with all target groups. Temporal patterns of islandwide mean macroinvertebrate density around Asuncion—from towed-diver benthic surveys during MARAMP 2003, 2005, and 2007—are shown later in this section (Figs. 15.7.1b, d, f and h).

Giant Clams

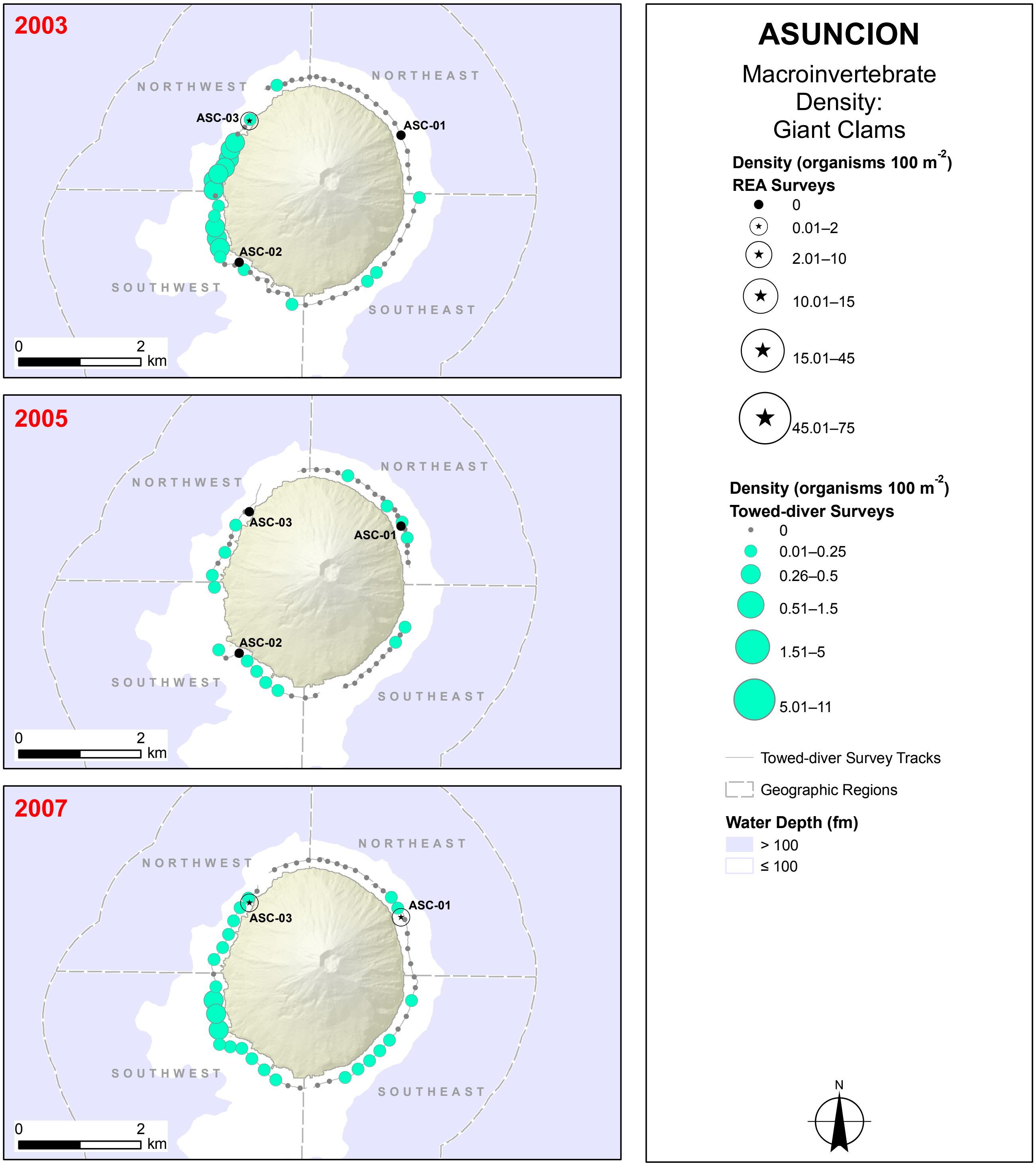


Figure 15.7.1a. Densities (organisms 100 m^{-2}) of giant clams from REA and towed-diver benthic surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007.

During MARAMP 2003, species of *Tridacna* giant clams were observed at 1 of the 3 REA sites surveyed and in 5 of the 6 towed-diver surveys conducted around Asuncion. REA site ASC-03 in the northwest region had a density of 1 organism 100 m^{-2}. The islandwide mean density from towed-diver surveys was 0.073 organisms 100 m^{-2} (SE 0.017). Among all towed-diver surveys around this island, the survey completed in the northwest region had the highest mean density of giant clams with 0.252 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 0.431 organisms 100 m^{-2} (Fig. 15.7.1a, top panel). The second-greatest mean density of giant clams from a towed-diver survey was 0.149 organisms 100 m^{-2}, recorded in the southwest region; segment densities ranged from 0 to 0.412 organisms 100 m^{-2}.

During MARAMP 2005, no giant clams were observed at the 3 REA sites surveyed at Asuncion, but all 5 towed-diver surveys had recordings of giant clams with an islandwide mean density of 0.034 organisms 100 m^{-2} (SE 0.009). Among all towed-diver surveys around this island, the survey completed in the southwest region had the highest mean density with 0.045 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 0.108 organisms 100 m^{-2} (Fig. 15.7.1a, middle panel).

During MARAMP 2007, giant clams were observed at both of the REA sites surveyed and in 4 of the 5 towed-diver surveys conducted around Asuncion. The overall mean density of giant clams from REA surveys was 0.5 organisms 100 m^{-2} (SE 0.17), and the islandwide mean density from towed-diver surveys was 0.055 organisms 100 m^{-2} (SE 0.012). Survey results suggest that giant clams were most abundant at ASC-03 in the northwest region with 0.67 organisms 100 m^{-2} (Fig. 15.7.1a, bottom panel). Among all towed-diver surveys around Asuncion, the survey completed in the southwest region had the highest mean density of giant clams with 0.123 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 0.358 organisms 100 m^{-2}.

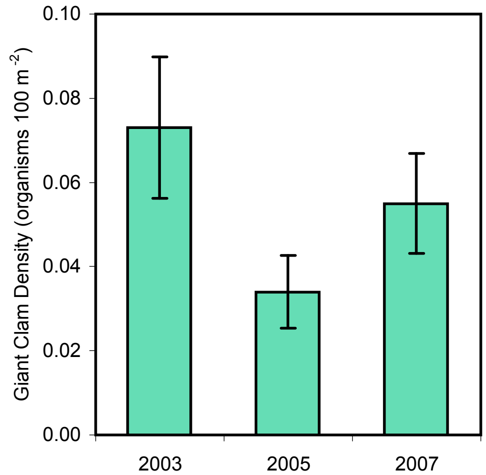


Figure 15.7.1b. Temporal comparison of mean densities (organisms 100 m^{-2}) of giant clams from towed-diver benthic surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. Error bars indicate standard error (± 1 SE) of the mean.

Towed-diver surveys suggested low abundance of giant clams around Asuncion during the 3 MARAMP survey periods, relative to the rest of the Mariana Archipelago (Fig. 15.7.1b). Although densities were low, the highest concentrations of giant clams resided along the west coast in each of the 3 MARAMP survey years. Minor fluctuations in density were observed, but this variation is not necessarily indicative of changes in the population structure of giant clams (for information about data limitations, see Chapter 2: "Methods and Operational Background," Section 2.4: "Reef Surveys").

Crown-of-thorns Seastars

During MARAMP 2003, no crown-of-thorns seastars (*Acanthaster planci*) were observed at the 3 REA sites surveyed or in the 6 towed-diver surveys conducted around Asuncion (Fig. 15.7.1c, top panel).

During MARAMP 2005, no COTS were observed at the 3 REA sites surveyed, but 2 of the 5 towed-diver surveys conducted around Asuncion had recordings of COTS with an overall mean density of 0.027 organisms 100 m^{-2} (SE 0.011). Among all towed-diver surveys around Asuncion, the survey completed in the northwest region had the highest mean density of COTS with 0.006 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 0.056 organisms 100 m^{-2} (Fig. 15.7.1c, middle panel).

During MARAMP 2007, COTS were observed at 1 of the 2 REA sites surveyed and in 2 of the 5 towed-diver surveys conducted around Asuncion. ASC-03 in the northwest region had a density of 1.667 organisms 100 m^{-2}. The islandwide mean density from towed-diver surveys was 0.029 organisms 100 m^{-2} (SE 0.011). The survey completed in the northwest region had the highest density of COTS with 0.117 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 0.445 organisms 100 m^{-2} (Fig. 15.7.1c, bottom panel). The second-greatest mean COTS density from a towed-diver survey was 0.035 organisms 100 m^{-2}, recorded in the southwest region; segment densities ranged from 0 to 0.164 organisms 100 m^{-2}.

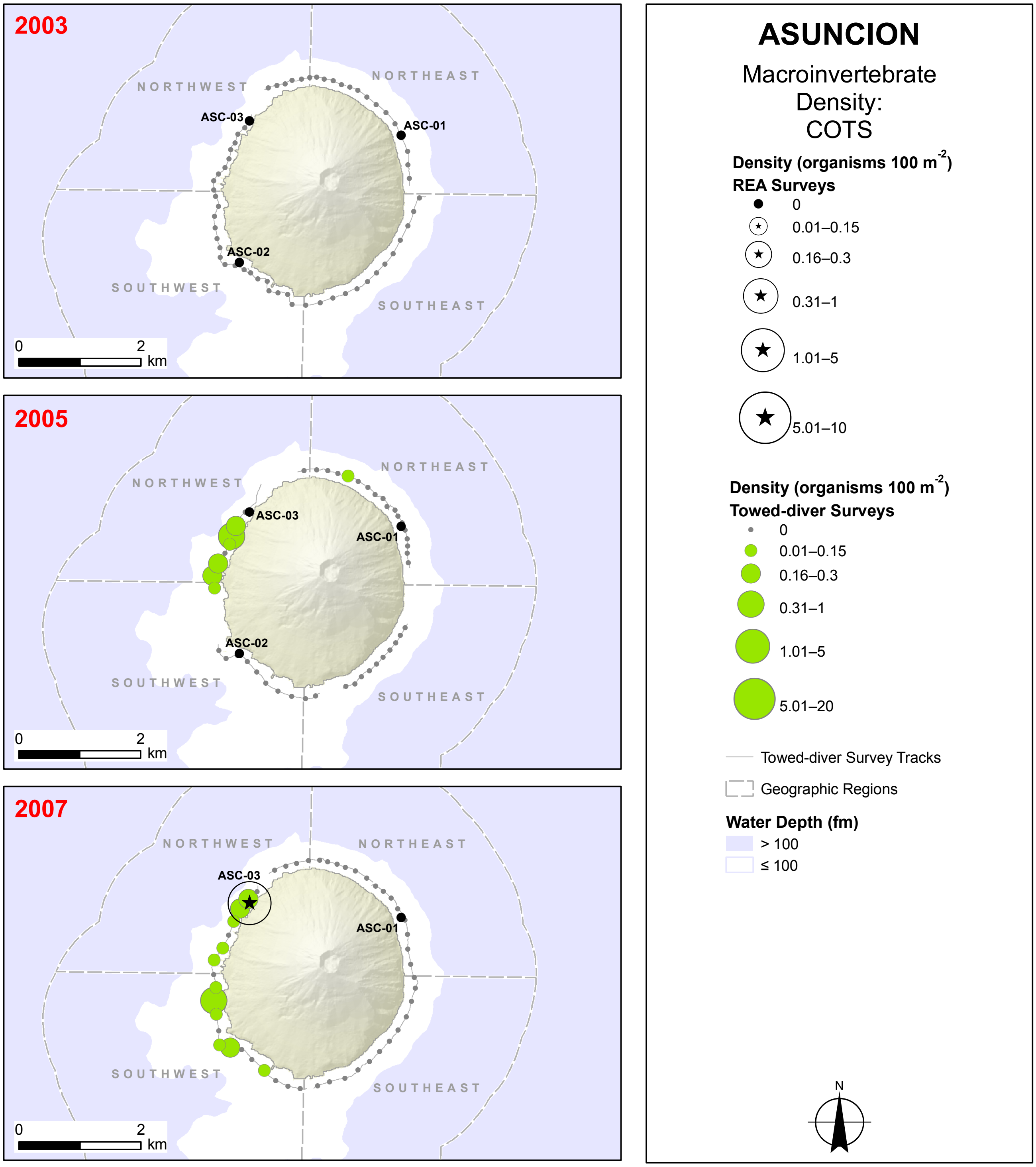


Figure 15.7.1c. Densities (organisms 100 m^{-2}) of COTS from REA and towed-diver benthic surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007.

No observations of COTS were made in towed-diver surveys conducted around Asuncion during MARAMP 2003. However, COTS were recorded during the other survey periods, particularly in the northwest region in 2005 and in the northwest and southwest regions in 2007 (Fig. 15.7.1d). The higher density observed in 2005, versus results from 2003, may have been a reflection of a recruitment pulse of COTS to Asuncion as an increased level of COTS density persisted in 2007. This change will have to be monitored more closely during additional MARAMP cruises. Density of this corallivorous seastar naturally fluctuates with food availability and variation in recruitment success (Birkeland and Lucas 1990; Fabricius et al. 2010; Yamaguchi 1987).

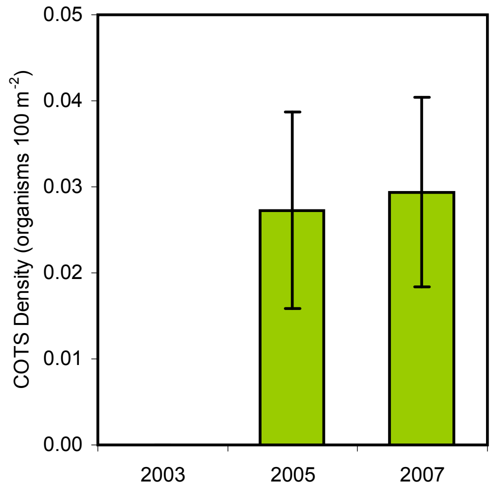


Figure 15.7.1d. Temporal comparison of COTS mean densities (organisms 100 m^{-2}) from towed-diver benthic surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. Error bars indicate standard error (± 1 SE) of the mean.

Sea Cucumbers

During MARAMP 2003, sea cucumbers were observed at 1 of the 3 REA sites surveyed and in 2 of the 6 towed-diver surveys conducted around Asuncion (Fig. 15.7.1e, top panel). ASC-02 had a density of 1 organism 100 m^{-2}; the observed sea cucumber was from the genus *Holothuria*. The islandwide mean density from towed-diver surveys was 0.002 organisms 100 m^{-2} (SE 0.001). The towed-diver survey completed in the northwest region had the highest mean density of sea cucumbers with 0.007 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 0.069 organisms 100 m^{-2} (Fig. 15.7.1e, top panel).

During MARAMP 2005, no sea cucumbers were observed at the 3 REA sites surveyed at Asuncion, and only 1 of the 5 towed-diver surveys conducted had recordings of sea cucumbers, with a mean density of 0.005 organisms 100 m^{-2} (SE 0.071); segment densities from this survey ranged from 0 to 0.075 organisms 100 m^{-2} (Fig. 15.7.1e, middle panel).

During MARAMP 2007, no sea cucumbers were observed at the 2 REA sites surveyed at Asuncion, and only 2 of the 5 towed-diver surveys conducted had recordings of sea cucumbers, with an islandwide mean density of 0.012 organisms 100 m^{-2} (SE 0.006). The towed-diver survey completed in the northwest region had the highest mean density of sea cucumbers with 0.055 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 0.312 organisms 100 m^{-2} (Fig. 15.7.1e, bottom panel).

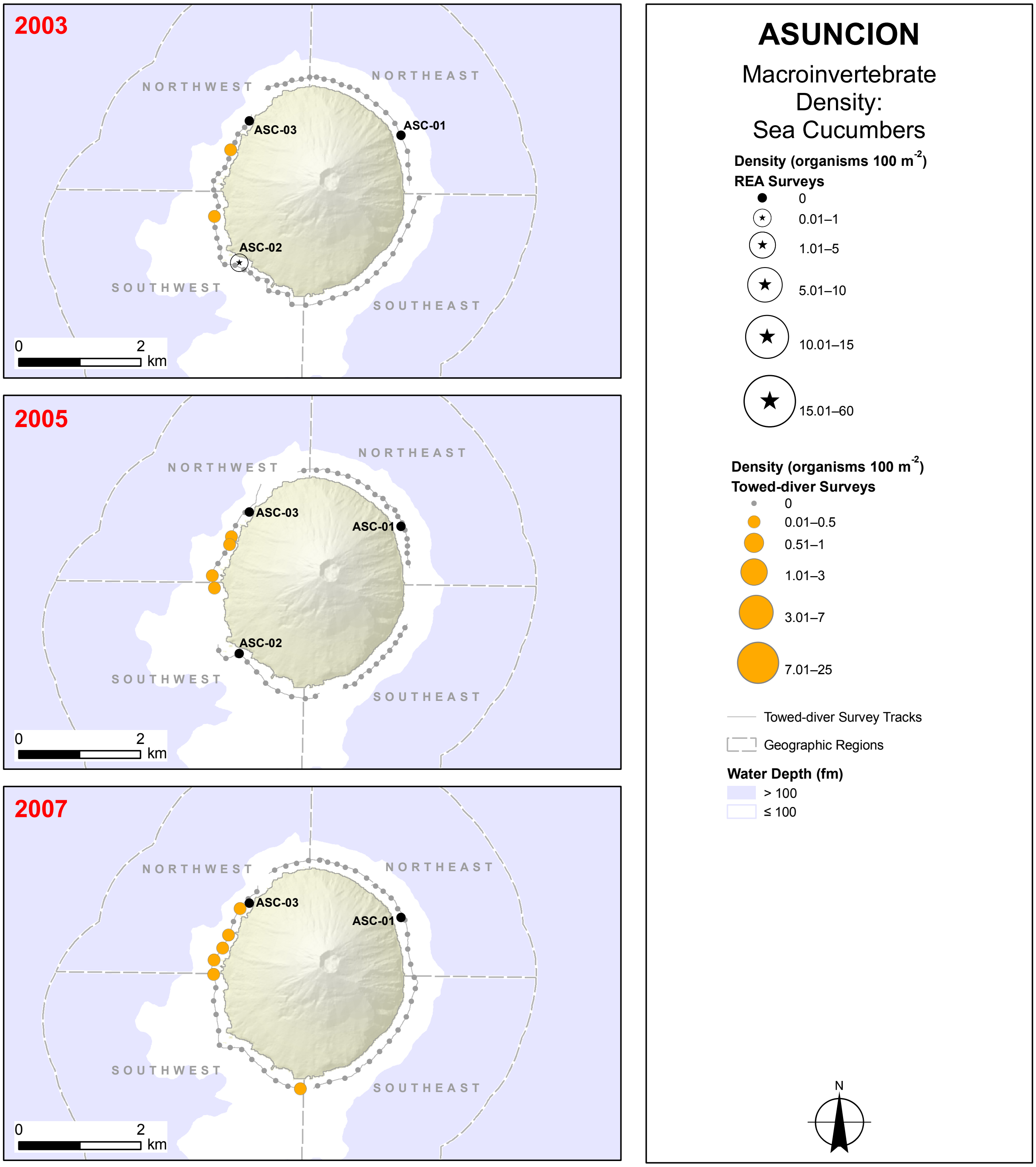


Figure 15.7.1e. Densities (organisms 100 m^{-2}) of sea cucumbers from REA and towed-diver benthic surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007.

Towed-diver surveys suggested low daytime abundance of sea cucumbers around Asuncion during MARAMP 2003, 2005, and 2007, relative to the rest of the Mariana Archipelago (Fig. 15.7.1f). Sea cucumbers were observed only in the northwest and southwest regions. Minor fluctuations in densities are not necessarily indicative of changes in the population structure of sea cucumbers (for information about data limitations, see Chapter 2: "Methods and Operational Background," Section 2.4: "Reef Surveys").

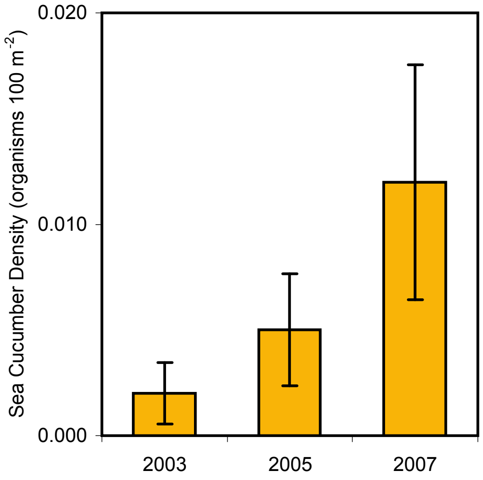


Figure 15.7.1f. Temporal comparison of mean densities (organisms 100 m^{-2}) of sea cucumbers from towed-diver benthic surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. Error bars indicate standard error (± 1 SE) of the mean.

Sea Urchins

During MARAMP 2003, sea urchins were observed at the 3 REA sites surveyed and in 4 of the 6 towed-diver surveys conducted around Asuncion. The overall mean density from REA surveys was 4.67 organisms 100 m^{-2} (SE 2.03), and the islandwide mean density from towed-diver surveys was 0.144 organisms 100 m^{-2} (SE 0.07). Survey results suggest that sea urchins were most abundant at ASC-02 in the southwest region with 8 organisms 100 m^{-2} (Fig. 15.7.1g, top panel). All observations at this site were species of the genus *Echinothrix*. Other genera observed at Asuncion during REA surveys, in low numbers, included *Echinostrephus*, a genus of rock-boring urchins. Among all towed-diver surveys around Asuncion, the survey completed in the northwest region had the highest mean density of sea urchins with 0.48 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 2.37 organisms 100 m^{-2}.

During MARAMP 2005, sea urchins were observed at 1 of the 3 REA sites surveyed and in 3 of the 5 towed-diver surveys conducted around Asuncion. ASC-02 had a density of 1 organism 100 m^{-2}; the observed sea urchin was from the genus *Echinostrephus.* The islandwide mean density from towed-diver surveys was 0.11 organisms 100 m^{-2} (SE 0.07). Among all towed-diver surveys around Asuncion, the survey completed in the northeast region had the highest mean density of sea urchins with 0.26 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 2.39 organisms 100 m^{-2} (Fig. 15.7.1g, middle panel).

During MARAMP 2007, sea urchins were observed at both REA sites surveyed and in 3 of the 5 towed-diver surveys conducted around Asuncion. Both ASC-01 and ASC-02 had a mean density of sea urchins of 0.33 organisms 100 m^{-2}, and, at both sites, only rock-boring urchins from the genus *Echinostrephus* were observed. The islandwide mean density from towed-diver surveys was 0.62 organisms 100 m^{-2} (SE 0.25). Among all towed-diver surveys around Asuncion, the survey completed in the southeast region had the highest mean density of sea urchins with 2.02 organisms 100 m^{-2}; segment densities from this survey ranged from 0 to 7.35 organisms 100 m^{-2} (Fig. 15.7.1g, bottom panel). The second-greatest mean density of sea urchins from a towed-diver survey was 1.02 organisms 100 m^{-2}, recorded in the southwest region; segment densities ranged from 0 to 6.97 organisms 100 m^{-2}.

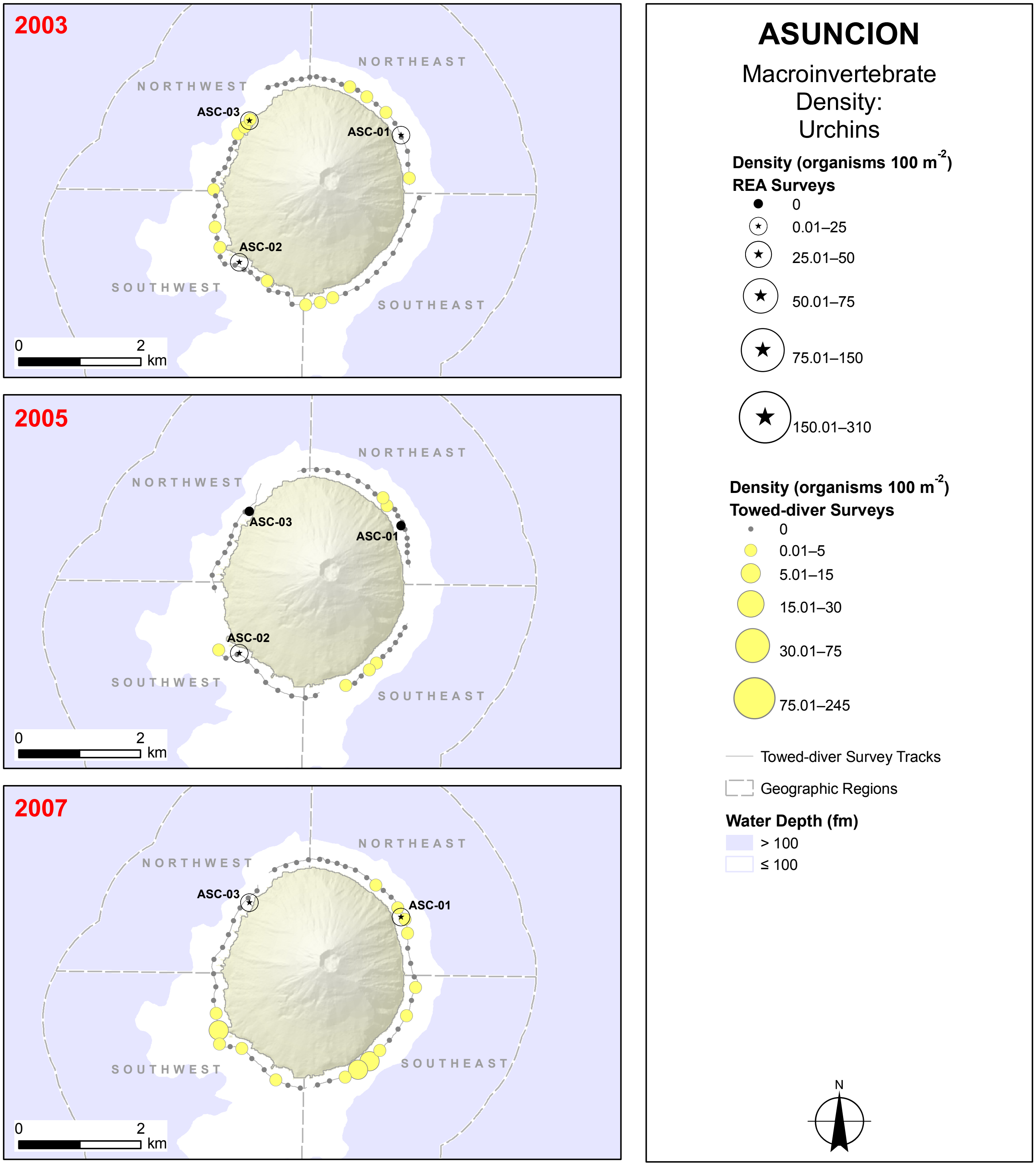


Figure 15.7.1g. Densities (organisms 100 m^{-2}) of sea urchins from REA and towed-diver benthic surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007.

Towed-diver surveys suggested extremely low abundance of sea urchins around Asuncion during MARAMP 2003, 2005, and 2007, compared to the rest of the Mariana Archipelago (Fig. 15.7.1h). The temporal fluctuations in densities are not necessarily indicative of changes in the population structure of sea urchins (for information about data limitations, see Chapter 2: "Methods and Operational Background," Section 2.4: "Reef Surveys").

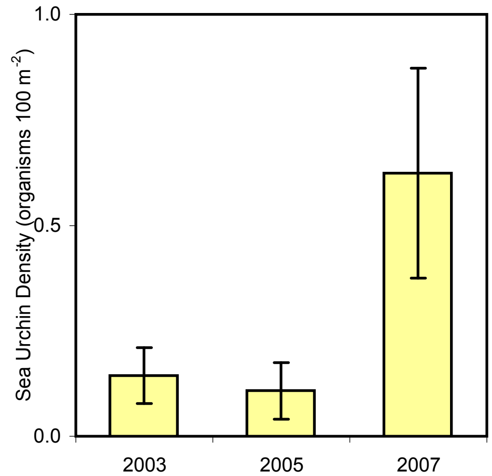


Figure 15.7.1h. Temporal comparison of mean densities (organisms 100 m^{-2}) of sea urchins from towed-diver benthic surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. Error bars indicate standard error (± 1 SE) of the mean.

15.8 Reef Fishes

15.8.1 Reef Fish Surveys

Large-fish Biomass

During MARAMP 2003, 6 towed-diver surveys for large fishes (≥ 50 cm in total length [TL]) were conducted in forereef habitats around the island of Asuncion. The overall estimated mean biomass of large fishes around this island, calculated as weight per unit area, was 2.12 kg 100 m^{-2} (SE 0.26). Observed large-fish biomass was highest in the southeast and southwest regions, where sharks were common (Fig. 15.8.1a, top panel). Snappers (Lutjanidae), reef sharks (Carcharhinidae), and nurse sharks (Ginglymostomatidae) constituted the largest proportion (80%) of the islandwide mean biomass of large fishes. Snappers alone contributed 35% of overall large-fish biomass. The twinspot snapper (*Lutjanus bohar*) was the dominant snapper species by biomass, contributing 0.51 kg 100 m^{-2} to islandwide large-fish biomass. Reef sharks accounted for 34% or 0.71 kg 100 m^{-2} of the overall large-fish biomass. The grey reef shark (*Carcharhinus amblyrhynchos*) was the largest contributor to biomass of reef sharks with 0.62 kg 100 m^{-2}. Nurse sharks also were common, with the tawny nurse shark (*Nebrius ferrugineus*) contributing 0.24 kg 100 m^{-2} of islandwide mean large-fish biomass.

During MARAMP 2005, 5 towed-diver surveys for large fishes (≥ 50 cm in TL) were conducted in forereef habitats around Asuncion. The overall estimated mean biomass of large fishes around this island was 1.81 kg 100 m^{-2} (SE 0.45), similar to biomass observed in 2003. As in 2003, observed large-fish biomass in 2005 was highest in the southeast and southwest regions, where sharks were common (Fig. 15.8.1a, middle panel). Reef sharks and nurse sharks dominated observations of large fishes and accounted for the greatest proportion (76%) or 1.38 kg 100 m^{-2} of islandwide mean large-fish biomass. The grey reef shark was the dominant shark species by biomass with 0.95 kg 100 m^{-2}. During this survey period, 60 sharks were observed, with 30 individuals recorded during a single survey. Although sharks were abundant, many of the grey reef sharks observed were smaller than 100 cm in TL, which is below the size of sexual maturity (120–150 cm in TL) for this species.

During MARAMP 2007, 5 towed-diver surveys for large fishes (≥ 50 cm in TL) were conducted in forereef habitats around Asuncion. The overall observed mean biomass of large fishes around this island was at 0.78 kg 100 m^{-2} (SE 0.21), lower than estimates made in 2003 and 2005. The highest observed large-fish biomass was found in the northeast region, where sharks and snappers were common (Fig. 15.8.1a, bottom panel). Snappers accounted for the greatest proportion (40%) or 0.31 kg 100 m^{-2} of islandwide mean large-fish biomass. The black and white snapper (*Macolor niger*) and twinspot snapper were the 2 main snapper species by biomass with 0.17 and 0.12 kg 100 m^{-2}. During this survey period, 13 sharks were observed: 8 grey reef sharks; 3 whitetip reef sharks (*Triaenodon obsesus*), and 2 tawny nurse sharks.

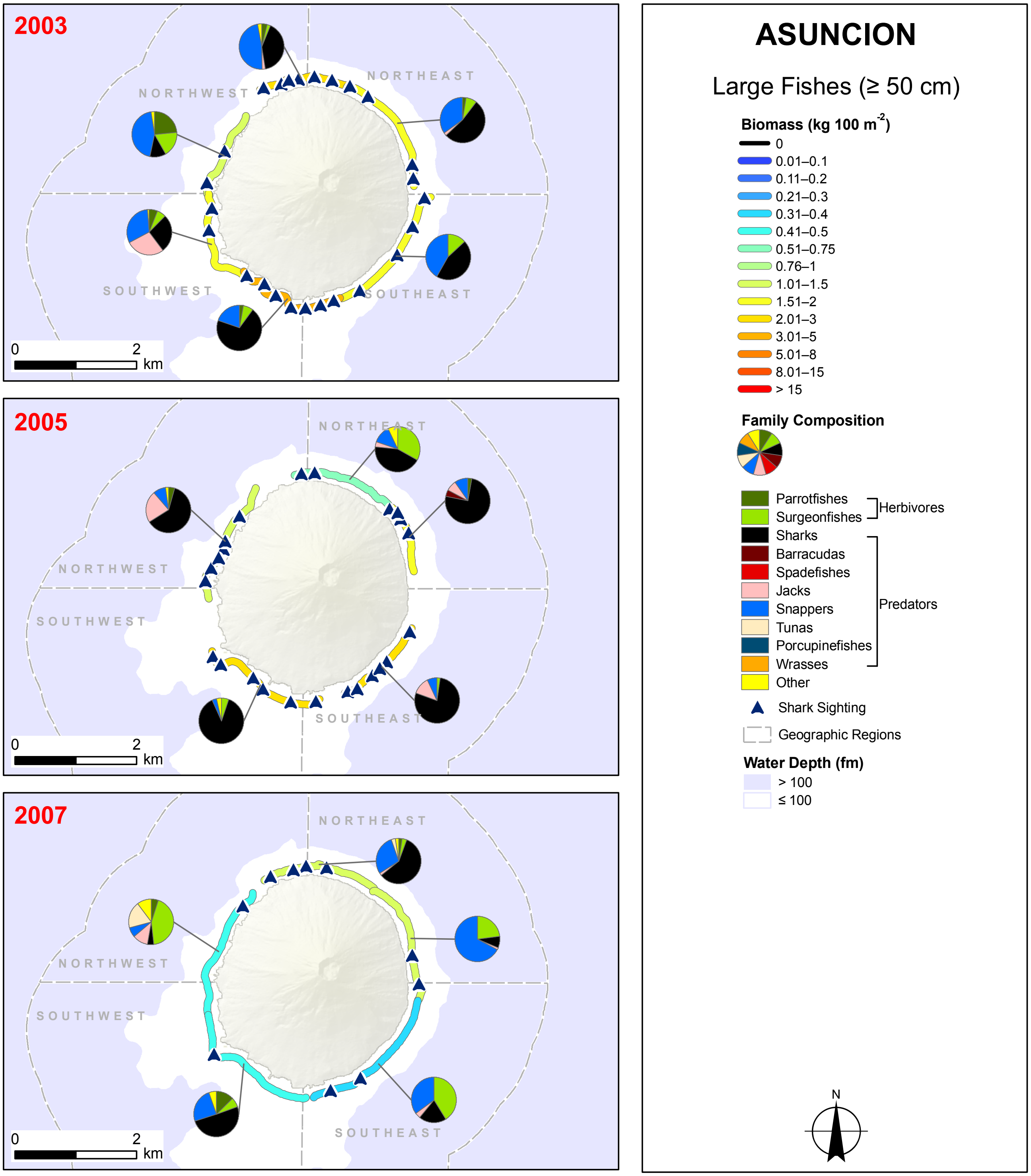


Figure 15.8.1a. Observations of large-fish (≥ 50 cm in TL) biomass (kg 100 m^{-2}), family composition, and shark sightings from towed-diver fish surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007. Each blue triangle represents a sighting of one or more sharks recorded inside or outside of the survey area over which it is shown.

Large-fish biomass from towed-diver surveys of forereef habitats was lower during MARAMP 2007, with an islandwide mean of 0.78 kg 100 m^{-2} (SE 0.21), than during MARAMP 2003 and 2005, when islandwide means were 2.12 kg 100 m^{-2} (SE 0.26) in 2003 and 1.81 kg 100 m^{-2} (SE 0.45) in 2005 (Fig. 15.8.1b). However, large-fish biomass at Asuncion, with an overall mean of 1.57 kg 100 m^{-2} (SE 0.40) across the 3 survey periods, was the second-highest level recorded among the northern islands (estimated biomass was higher only at Farallon de Pajaros). Reef sharks and nurse sharks contributed the greatest percentages of large-fish biomass over the 3 survey periods, with the grey reef shark as the most abundant shark

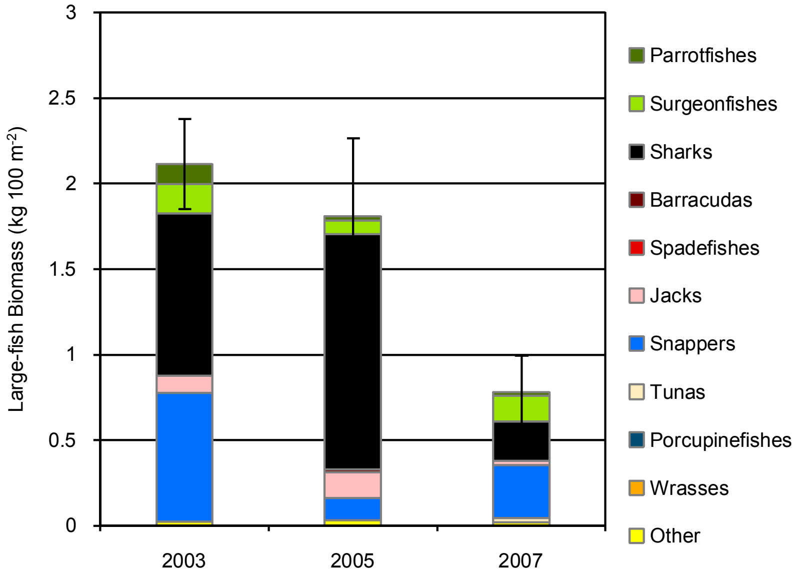


Figure 15.8.1b. Temporal comparison of mean values of large-fish (≥ 50 cm in TL) biomass (kg 100 m^{-2}) from towed-diver fish surveys of forereef habitats conducted around Asuncion during MARAMP 2003, 2005, and 2007. Error bars indicate standard error (± 1 SE) of the mean.

species recorded. The size of grey reef sharks observed was unusual, with many estimated to be smaller than 100 cm in TL. Snappers also were common during the 3 MARAMP survey periods, and the twinspot snapper, the black and white snapper, and the midnight snapper (*Macolor macularis*) were the most abundant snapper species. Other notable observations included sightings of the spotted knifejaw (*Oplignathus punctatus*), which was generally rare in the Mariana Archipelago.

Total Fish Biomass

Total fish biomass for the 3 REA sites surveyed in forereef habitats at Asuncion during MARAMP 2003 was somewhat below the average of the northern islands, with an overall sample mean of 7.39 kg 100 m^{-2} (SE 0.65). The highest biomass of 8.28 kg 100 m^{-2} was observed at REA site ASC-01 in the northeast region (Fig. 15.8.1c, top panel). Surgeonfishes (Acanthuridae), snappers, and fusiliers (Caesionidae) accounted for the greatest proportions of total fish biomass: 20%, 13%, and 13%. The orangespine unicornfish (*Naso lituratus*) was the dominant surgeonfish species by biomass, and the twinspot snapper was the main snapper species by biomass. Fusiliers were abundant at ASC-03, located in the northwest region, where schools of the yellow and blueback fusilier (*Caesio terres*) and Marr's fusilier (*Pterocaesio marri*) were observed.

Based on REA surveys conducted during MARAMP 2003, species richness was variable among the 3 sites surveyed with a range of 25–38 species 100 m^{-2}. The highest diversity was found at ASC-03 in the northwest region (Fig. 15.8.1c, top panel). Wrasses (Labridae) and surgeonfishes composed the 2 most represented families with 24 and 18 species observed. The ornate wrasse (*Halichoeres ornatissimus*) was the most numerically abundant wrasse species, and the orangespine unicornfish was the most numerically abundant surgeonfish species. Damselfishes (Pomacentridae) were the most numerically abundant fish taxa overall, with Vanderbilt's chromis (*Chromis vanderbilti*) dominating counts with over 100 individuals 100 m^{-2} observed.

Total fish biomass for the 3 REA sites surveyed in forereef habitats at Asuncion during MARAMP 2005 was the highest level recorded in the Mariana Archipelago in this survey period, with an overall sample mean of 26.36 kg 100 m^{-2} (SE 1.42). Biomass was nearly uniformly high across the 3 sites, with site-specific biomass ranging from 24.87 to 29.20 kg 100 m^{-2} (Fig. 15.8.1c, middle panel). Reef sharks accounted for the largest proportion (28%) of total fish biomass. During this survey period, 12 sharks were observed: 10 gray reef sharks and 2 whitetip reef sharks. At least 1 shark was observed at all 3 of the sites in 2005. Surgeonfishes, chubs (Kyphosidae), and snappers also were large contributors to total fish biomass. The orangespine unicornfish accounted for the largest proportion (22%) of surgeonfish biomass. The humpback red snapper (*Lutjanus gibbus*) and twinspot snapper together constituted 98% of snapper biomass.

Based on REA surveys conducted during MARAMP 2005, species richness was high at Asuncion with a range of 40–45 species 100 m^{-2}. The highest diversity was seen at ASC-03 in the northwest region (Fig. 15.8.1c, middle panel). Consistent with observations made in 2003, wrasses and surgeonfishes composed the 2 most represented families with 21 and 15 species observed. The ornate wrasse was again the most numerically abundant wrasse species, while the brown surgeonfish (*Acanthurus nigrofuscus*) was the most abundant surgeonfish species. Damselfishes were the most abundant fish taxa overall, and the midget chromis (*Chromis acares*) dominated counts with more than 200 individuals 100 m^{-2} observed.

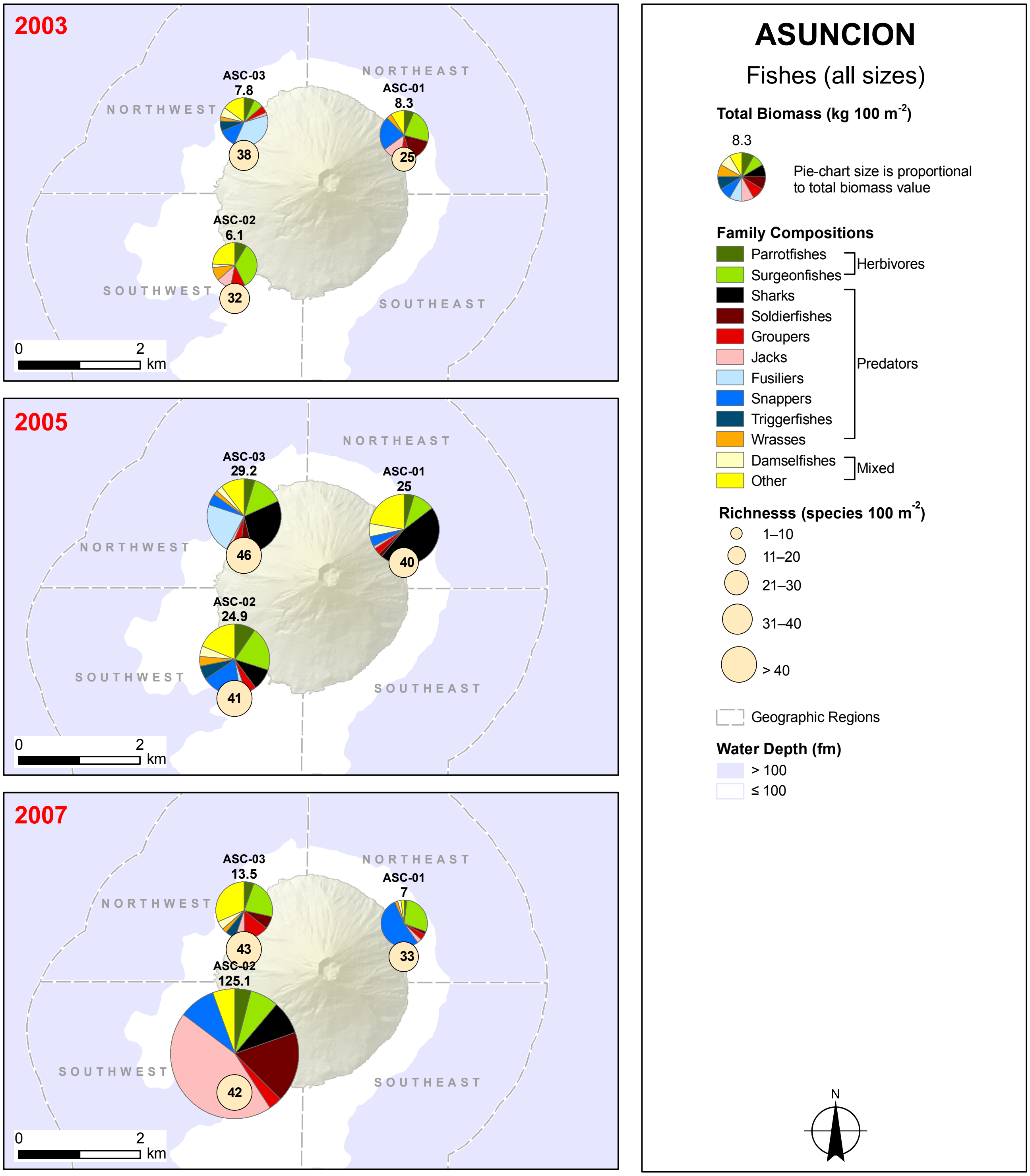


Figure 15.8.1c. Observations of total fish biomass (all species and size classes in kg 100 m^{-2}), family composition, and species richness (species 100 m^{-2}) from REA fish surveys using the belt-transect method in forereef habitats at Asuncion during MARAMP 2003, 2005, and 2007.

Total fish biomass for the 3 REA sites surveyed in forereef habitats at Asuncion during MARAMP 2007 was the highest level observed in the Mariana Archipelago in the any of the 3 survey periods, with an overall sample mean of 48.54 kg 100 m^{-2} (SE 38.31). This very high value was partly a consequence of the observation at ASC-02 of 6 large giant trevally (*Caranx ignobilis*), each with estimated TL > 100 cm (Fig. 15.8.1c, bottom panel). Jacks (Carangidae) alone contributed 38% of total fish biomass. Soldierfishes (Holocentridae) accounted for the second-greatest proportion (16%) of total fish biomass, and surgeonfishes and snappers each made up another ~ 10% of total fish biomass

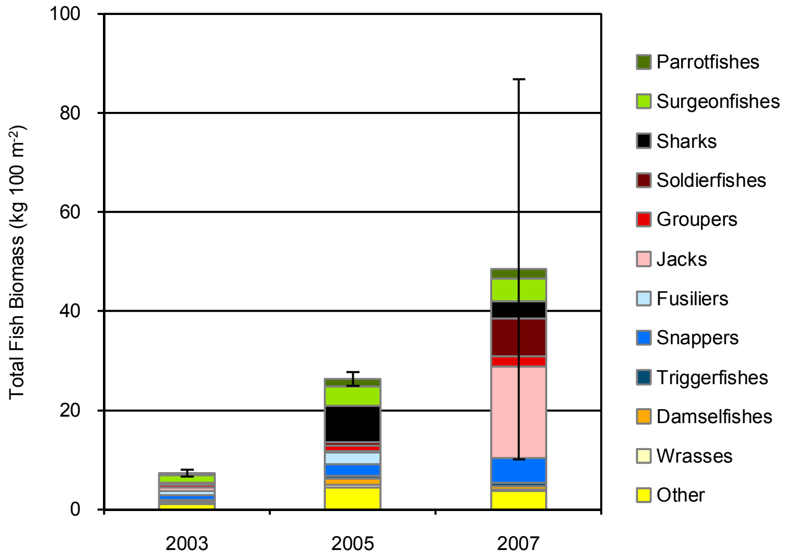


Figure 15.8.1d. Temporal comparison of mean values of total fish biomass (all species and size classes in kg 100 m^{-2}) from REA fish surveys of forereef habitats conducted at Asuncion during MARAMP 2003, 2005, and 2007. Error bars indicate standard error (± 1 SE) of the mean.

(4.63 and 5.01 kg 100 m^{-2}). The blotcheye soldierfish (*Myripristis berndti*) was the major soldierfish species and made up more than 90% of soldierfish biomass. Snappers and surgeonfishes also were common at Asuncion, contributing 5.01 kg 100 m^{-2} and 4.63 kg 100 m^{-2} to total fish biomass.

Based on REA surveys conducted during MARAMP 2007, species richness was moderate with a range of 33–43 species 100 m^{-2}. The highest diversity was found at ASC-03 in the northwest region (Fig. 15.8.1c, bottom panel). Wrasses and surgeonfishes composed the 2 most represented families with 19 and 18 species observed. Planktivorous fishes dominated counts with damselfishes again observed as the most abundant fish taxa overall. The midget chromis was by far the most abundant damselfish species with more than 300 individuals 100 m^{-2} recorded. The amethyst anthias (*Pseudanthias pascalus*) was the second-most numerically abundant species with more than 100 individuals 100 m^{-2} observed.

No clear spatial patterns were evident for total fish biomass in forereef habitats at Asuncion during the 3 MARAMP survey years. When compared with the rest of the Mariana Archipelago, estimated reef fish biomass was very high. The overall mean biomass across the 3 survey periods of 27.43 kg 100 m^{-2} (SE 11.89) was the highest observed at any island, reef, or bank in the Mariana Archipelago. Snappers and surgeonfishes made up substantial portions of total fish biomass in each of the 3 MARAMP survey periods, collectively accounting for 20%–33% of total fish biomass per survey year (Fig. 15.8.1d).

Mean species richness ranged from 32–42 species 100 m^{-2} for the 3 MARAMP survey periods. The highest diversity was found at ASC-03 in the northwest region, and the lowest species richness was seen at ASC-01 in the northeast region. Wrasses and surgeonfishes composed the 2 most represented families with an average of 21 and 16 species observed. Damselfishes were the most numerically abundant taxa of fishes overall, with the midget chromis and Vanderbilt's chromis dominating counts.

15.9 Marine Debris

15.9.1 Marine Debris Surveys

During MARAMP 2003, 2 sightings of derelict fishing gear were recorded in the 6 towed-diver surveys conducted on forereef habitats around the island of Asuncion (Fig. 15.9.1a). One sighting was documented in the northwest region, and another was noted in the southeast region. No additional descriptive information was recorded during towed-diver surveys. No munitions, wrecks, or other man-made objects were identified.

During MARAMP 2005, no marine debris sightings were recorded in the 5 towed-diver surveys conducted on forereef habitats around Asuncion.

During MARAMP 2007, 1 sighting of derelict fishing gear was recorded in the 5 towed-diver surveys conducted on forereef habitats around Asuncion: an old net located in the northeast region. No munitions, wrecks, or other man-made objects were identified.

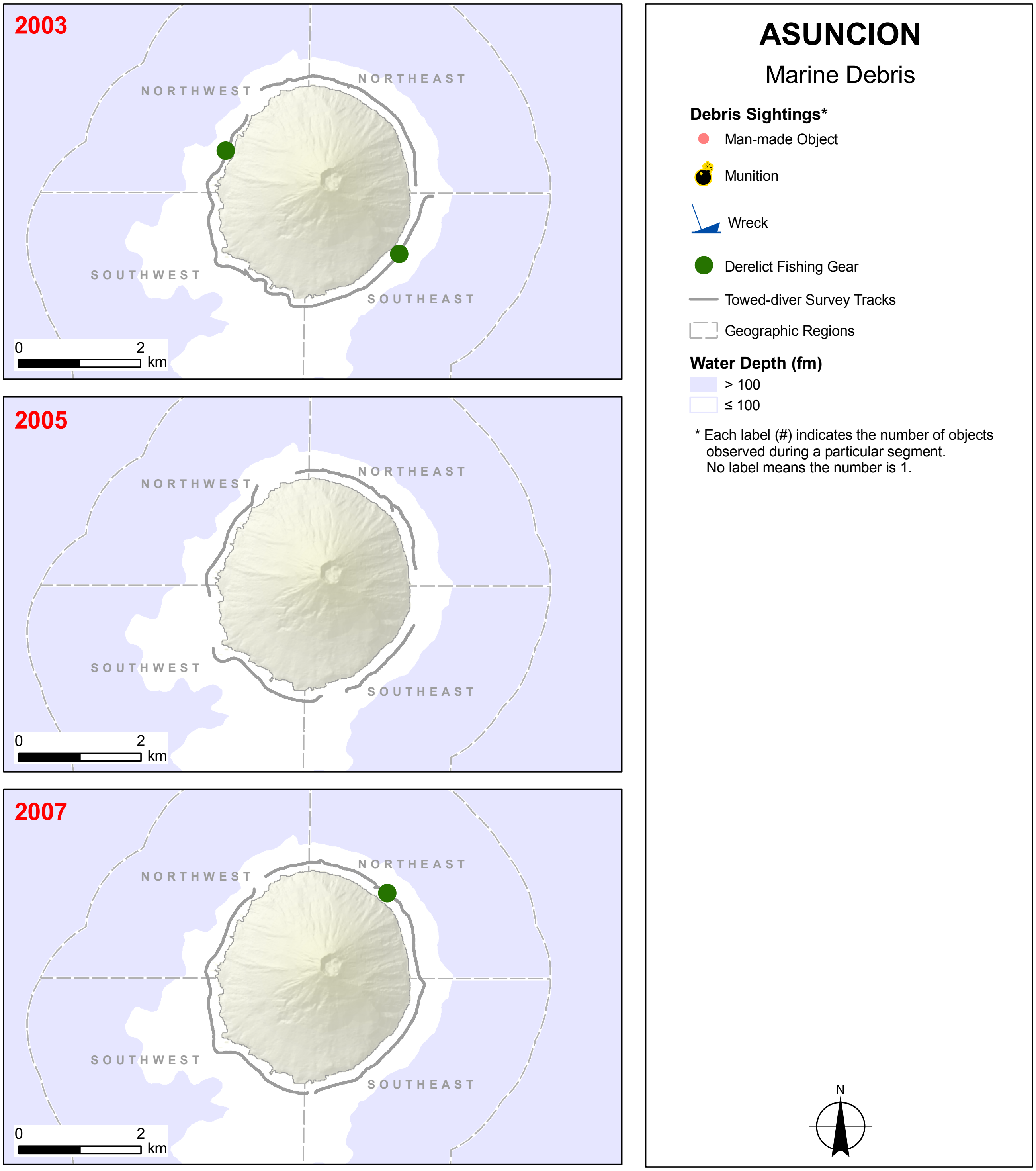


Figure 15.9.1a. Qualitative observations of marine debris from towed-diver benthic surveys of forereef habitats conducted around Asuncion during MARAMP 2003 and 2007. No debris was identified in 2005. Symbols indicate the presence of specific debris types.

Observations of debris are positive identifications, but absence of reports does not imply lack of debris. Since methods for observing marine debris varied between MARAMP surveys in 2003, 2005, and 2007, temporal comparisons are not appropriate. Debris sightings were recorded differently—with sightings in 2003 recorded as a direct part of diver observational methods and sightings in 2005 and 2007 recorded solely as incidental observations by the towed divers in their observer comments.

15.10 Ecosystem Integration

The spatial distributions and temporal patterns of individual coral reef ecosystem components around the island of Asuncion are discussed in the discipline-specific sections of this chapter. In this section, key ecological and environmental aspects are considered concurrently to identify potential relationships between various ecosystem components. In addition to this island-level analysis, evaluations on an archipelagic scale of different ecosystem elements and their potential relationships across the entire Mariana Archipelago are presented in Chapter 3: “Archipelagic Comparisons,” including archipelago-wide reef condition indices with ranks for Asuncion as well as the other 13 islands covered in this report.

Asuncion is the steepest of the northern volcanic islands of the Mariana Archipelago, a fact that is reflected in the onshore and submarine topography surrounding this island (Figs. 15.3.1b and c in Section 15:3.1: “Acoustic Mapping”). This steep terrain, in combination with predominant weather and oceanographic patterns (Fig. 15.10a), creates a dynamic environment and ultimately produces a unique ecosystem of varying habitat types.

The steepest slopes and highest sea cliffs, as well as the steepest submarine topography, occur on the northern and eastern sides of this island. Asuncion’s steep benthic habitat is characterized by rocky reef strewn with boulders that support little cover of macroalgae or live hard corals (Fig. 15.10a). The east coast of Asuncion experiences the predominant weather influences, including trade winds and high ambient and moderate-to-high episodic wave energy relative to the west coast (Fig. 15.10a), and these conditions likely cause currents on the eastern side. All of these factors contribute to the dynamic, frequently changing environment of this side of the island, and they may present difficulties for recruitment of benthic organisms.

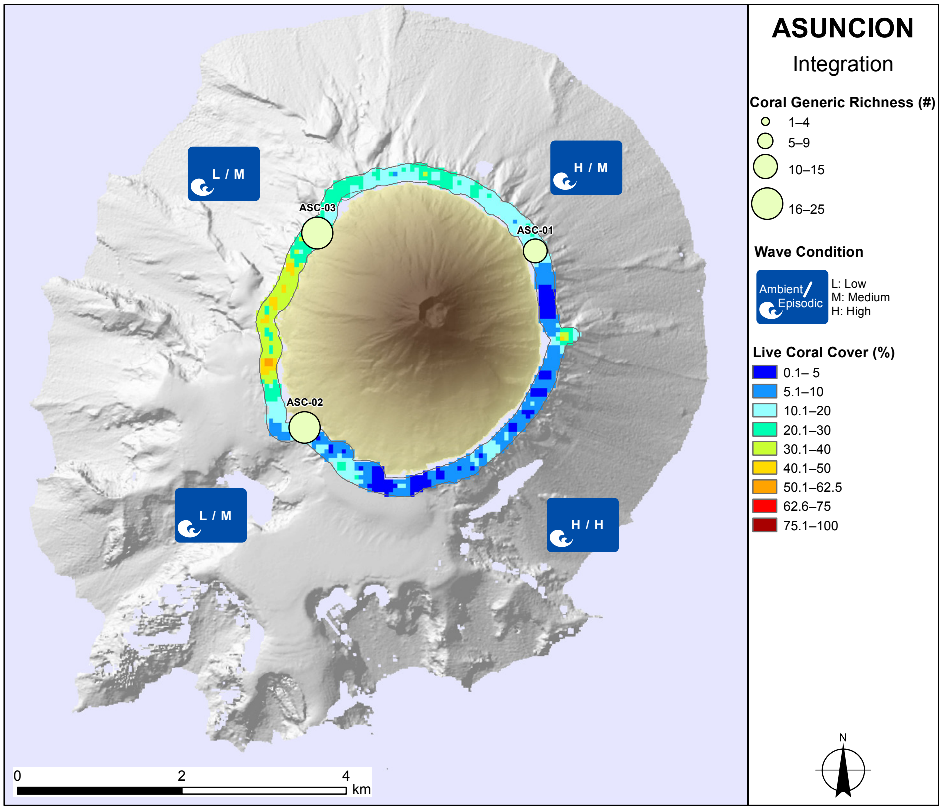
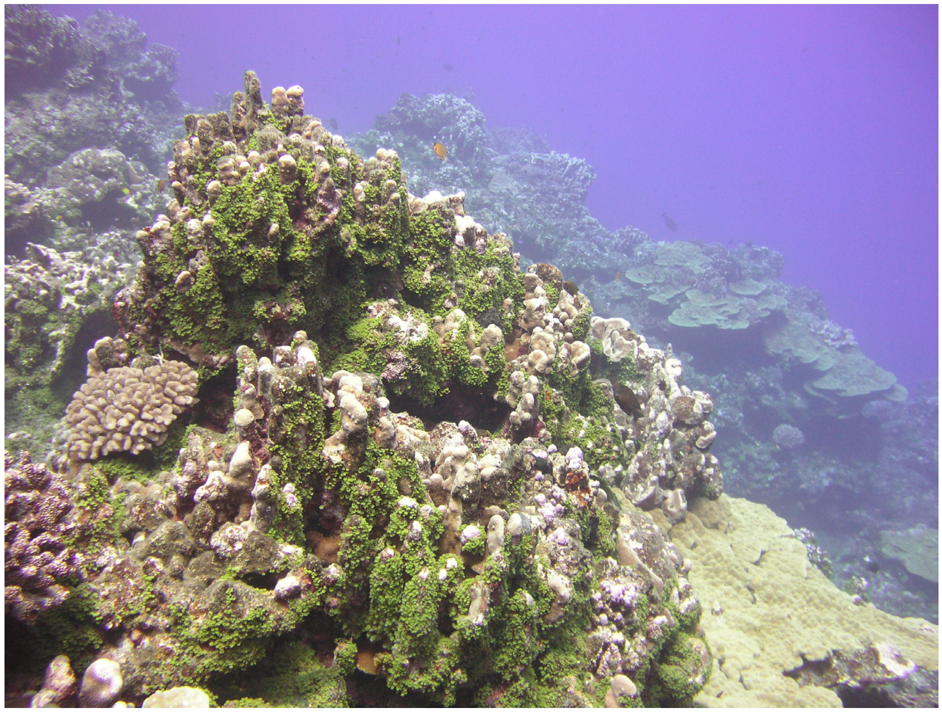


Figure 15.10a. Cover (%) observations of live hard corals from towed-diver surveys and generic richness from REA surveys conducted on forereef habitats around Asuncion during MARAMP 2003, 2005, and 2007. Values of coral cover represent interpolated values from the 3 MARAMP survey years, and generic-richness values represent averages of data from the 3 survey years. A large, blue icon indicates the level of ambient and episodic wave exposure for each geographic region. Underlying these data in grey scale is the hillshade bathymetry.

The southern and southwestern sides of Asuncion are characterized by less dramatic topside and benthic topography, resulting in a biological seascape that is very different from the rest of Asuncion. In these areas, submarine terraces extend up to 2 km from the shoreline (Fig. 15.3.1b in Section 15:3.1: “Acoustic Mapping”). The southern side of this volcano also is subject to frequent landslides. These landslides presumably carry substantial amounts of sediment and rock into nearshore waters. The shelves on the southern side of Asuncion are composed largely of sand and boulders, resulting in an environment of medium-low to medium complexity that supports little coral growth with estimated coral cover predominantly < 10% (Fig. 15.10a).

Figure 15.10b. Reef habitat on the west side of Asuncion. *NOAA photo by Robert Schroeder*



The west side of this island, including sections of the northwest and southwest regions, is marked by several ash deposits along the moderately steep slope of this volcano and by a shallow terrace that extends out from shore to below the surface (Fig. 15.3.1a). Sheltered from the prevailing weather patterns, this nearshore habitat provides prime reef-building conditions—as demonstrated by the high levels of live coral cover recorded in both REA and towed-diver surveys conducted in this area (Figs. 15.5.1a and b in Section 15:5.1: "Coral Surveys") and the high diversity recorded at REA site ASC-03 (Fig. 15.5.1b), relative to other surveyed areas at Asuncion. The reefs along the west coast also supported the highest coral-colony densities observed in 2003 and 2005, the highest crustose-coralline-red-algal cover, and the greatest macroalgal diversity observed at Asuncion during each of the 3 MARAMP survey years (Fig. 15.10b). The west side was notable for consistently supporting the greatest abundance of sea cucumbers, COTS, and giant clams observed around Asuncion.

Figure 15.10c. A diver observing a grey reef shark (*Carcharhinus amblyrhynchos*) during an REA fish survey at Asuncion. *NOAA photo by Robert Schroeder*

In the absence of any known fishing pressure, the waters surrounding Asuncion support abundant stocks of reef fishes compared to other islands of the Mariana Archipelago. Large-fish biomass, from towed-diver surveys, averaged over the 3 MARAMP survey periods was the second-highest level observed among the islands of the Mariana Archipelago (excluding the offshore banks) after Farallon de Pajaros (Fig. 15.8.1a in Section 15.8.1: "Reef Fish Surveys"). Results from REA surveys for fishes of all sizes and species also were high overall, with the average over the 3 survey periods being the highest total fish biomass estimated for this archipelago, and fish assemblages included a broad range of herbivorous and piscivorous species (Fig. 15.8.1c). High numbers of sharks were seen at Asuncion during the 3 survey years, compared to observations at other islands of the Mariana Archipelago (Fig. 15.10c).

15.11 Summary

MARAMP integrated ecosystem observations provide a broad range of information: bathymetry and geomorphology, oceanography and water quality, and biological observations of corals, algae, fishes, and benthic macroinvertebrates along the forereef habitats around Asuncion. Methodologies and their limitations are discussed in detail in Chapter 2: "Methods and Operational Background," and specific limitations of the data or analyses presented in this Asuncion chapter are included in the appropriate discipline sections. Methods information and technique constraints should be considered when evaluating the usefulness and validity of the data and analyses in this chapter. The conditions of the fish and benthic communities and the overall ecosystem around Asuncion, relative to all the other islands in the Mariana Archipelago, are discussed in Chapter 3: "Archipelagic Comparisons."

This section presents an overview of the status of coral reef ecosystems around the island of Asuncion as well as some of the key natural processes and anthropogenic activities influencing these ecosystems:

- Asuncion has a land area of 7.86 km^2 and is the third-most northerly island of the Mariana Archipelago.
- Asuncion is part of a protected reserve, established for the protection of habitat for birds, wildlife, and plants through the CNMI Constitution. The waters and submerged lands of Asuncion also are part of the Islands Unit of the Marianas Trench Marine National Monument, which was established by presidential proclamation in January 2009.
- Asuncion is the steepest of the northern volcanic islands, a fact reflected in its onshore and submarine topography. The east side of Asuncion is consistently much steeper than the western side.
- The reefs on the west side of Asuncion supported the highest levels of live coral cover seen at Asuncion, greatest coral-colony densities observed in 2003 and 2005, highest crustose-coralline-red-algal cover and macroalgal diversity observed in each of the 3 MARAMP survey years, and highest densities of giant clams, COTS, and sea cucumbers recorded around Asuncion.
- In the northern part of the northeast region, towed-diver surveys suggested habitats of medium to medium-high complexity and hard substrates supporting low levels of live-hard-coral cover. South of Asuncion, the seabed topography is dominated by a large, low-rugosity shelf composed of a number of terraces.
- Wave model output shows ambient trade wind swells impacting the northeast and southeast regions. Episodic wave energy from storm tracks impacts the southeast region and to a lesser extent the other 3 regions.
- In 2007, mean cover of live corals was 15.7% from the 3 REA sites surveyed using the line-point-intercept method at Asuncion. Overall mean live coral cover around Asuncion from towed-diver surveys ranged from 10% to 18% during the 3 MARAMP survey years.
- Coral-disease surveys in 2007 were conducted at 3 REA sites at Asuncion and detected 10 cases of disease. The overall mean prevalence from these sites was 0.02%. Two major disease conditions, fungal infection and skeletal growth anomalies, accounted for 80% and 20% of cases found on reefs at Asuncion.
- A TOAD survey conducted south of Asuncion at depths of 70–120 m over a distance of more than 1.4 km, revealed a dense aggregation of sea pens (order: Pennatulacea). Aggregations were recorded standing as high as ~ 30 cm and occurred on a soft substrate, possibly composed of basaltic sand.

- In this same area south of Asuncion, a decline in density of sea pens at a 120-m depth was associated with the occurrence of a patch of live hard corals that was 100 m long. Both corals and sea pens were observed near the east side of the steep-sided ledge that extends south from Asuncion and rises abruptly from the surrounding seafloor at a depth of ~ 600 m.

- Overall mean cover of macroalgae around Asuncion was higher in 2007 than in 2005. Dramatic increases in abundance of species of *Jania* were observed from 2003 to 2007. Only one coralline-algal disease, coralline lethal orange disease, was detected around Asuncion, at site ASC-02 in the southwest region.

- Overall large-fish biomass from towed-diver surveys for the 3 MARAMP survey periods combined was high relative to results from other islands of the Mariana Archipelago, second only to Farallon de Pajaros. Survey data indicated decreased large-fish biomass in 2007, when overall mean large fish biomass was 0.78 kg 100 m^{-2} versus the overall means of 2.12 and 1.81 kg 100 m^{-2} recorded in 2003 and 2005.

- During towed-diver surveys for large fishes, 54 sharks were observed in 2003, and 60 sharks were seen in 2005 with half of those recorded during a single towed-diver survey. Although sharks were abundant at Asuncion in 2005, many of the grey reef sharks (*Carcharhinus amblyrhynchos*) encountered were smaller than 100 cm in TL, which is below the size of sexual maturity (120–150 cm TL) for this species. In 2007, only 13 sharks were observed.

- When compared to the rest of the Mariana Archipelago, total fish biomass from REA surveys for fishes of all sizes and species was very high at Asuncion. The overall mean over the 3 MARAMP survey periods, 27.43 kg 100 m^{-2}, was the highest value for this archipelago.

- Densities of COTS were extremely low in 2003 and 2005, compared to survey results from other islands in the Mariana Archipelago; however, in the northwest region, the observed COTS density increased sharply in 2007.

- Sea cucumbers and sea urchins were observed at low densities at Asuncion during each of the 3 survey years and only reported from the west coast. Giant clams were fairly common along the west coast of Asuncion.